Updated Project Scope & Plan Report

Team 2

Electric Vehicle Range Extension

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ABSTRACT

Being a global leader in advanced power systems, Cummins Inc. has a large interest in the integration and performance of electrical and mechanical systems working together. Cummins has tasked Team 2 to extend the range of an electric vehicle by at least 15% through non-traditional power methods while minimizing the reduction in performance or increasing the onboard fuel supply. Team 2 has approached this goal by first inspecting the vehicle platform we were given and by conducting extensive research on external power sources and systems. Through a needs assessment and several design tools, we have selected and are currently procuring a solar roof replacement for the vehicle, while also implementing a better generator-battery hybrid design into our vehicle circuitry. So far, the team has completed benchmark range testing, concluding the current theoretical range to be approximately 96.1 miles. Wiring and hardware improvements have also been done to ensure component protection and circuitry organization. The external 280W solar roof replacement along with the increased efficiency of our generator-battery hybrid circuitry design will ensure that the ultimate goal is reached by our due date, given that we stay on track with our project schedule.

1. Project Scope

Our overall project scope has not been altered apart from slightly updated objectives to reflect our updated schedule and current project progression.

1.1 Project Background

Cummins, Inc is a global leader in the production, development, and service of various complex power systems. Cummins specializes in a large variety of diesel engines and alternative fuel generators, as well as the related components and technology. These power systems include but are not limited to the use of advanced batteries, upgraded electronics, and non-traditional power sources. In relation to this project, Cummins is clearly interested in the integration and performance of combining several power sources to achieve maximum efficiency.

The team was supplied with a 48V Tomberlin Electric Low Speed Vehicle, which can be seen in Figure 1 and was received in the condition left by last year's team, with the main addition of a propane generator. The 2015-2016 team had similar goals and constraints to the ones Team 2 has built on and developed below.

Figure 1. 48V Tomberlin Electric Low Speed Vehicle supplied to Team 2.

1.2 Need Statement

Our team was approached by Dr. Michael Hays of Cummins, Inc, to extend the range of an electric vehicle similar in size to a golf cart. The vehicle's range needs to be improved by 15% above its current capability. Dr. Hays wishes us to do so without increasing the fuel capacity of the vehicle and minimizing the reduction in performance. With this information, the following need statement was created.

"The current range of the cart is unsatisfactory and needs to be extended without adding fuel supply and minimizing the reduction in vehicle performance."

1.3 Goal Statement and Objectives

After thorough discussion with our adviser and sponsor along with a need assessment, our team formulated the following goal statement.

"To increase the range of the electric vehicle by at least 15% through non-traditional power adders while minimizing the reduction in acceleration and top speed."

Objectives:

- Procure/install additional power source
- Repair/finalize overall system circuitry
- Test/document increase in vehicle range
- Reconfigure overall vehicle circuitry
- Further optimize system to satisfy goals and constraints

1.4 Constraints

- Fuel supply cannot be increased
- Vehicle must be able to carry four people
- Top speed cannot be reduced by more than 10%
- Acceleration cannot be reduced by more than 10%

2. Methodology

Through the utilization of a needs assessment and discussions with both our faculty advisors and sponsor, a House of Quality was first developed to determine the most important design aspects of our project to be efficiency, durability, and power. These characteristics led us to develop several design concepts in which we ultimately decided upon using a Pugh Decision Matrix which can be seen below in Figure 2.

Criteria	**Weight**	**Photovoltaic Method**	**Regenerative Braking**	**Generator Optimization**
Cost	1	1	1	3
Performance	3	3	1	3
Reliability	2	3	3	3
Ease of Implementation	3	3	2	1
Total		**25**	**16**	**21**

Figure 2. A Pugh decision matrix was developed to compare design options.

A photovoltaic panel was chosen per our design criteria as our non-traditional power source to be added along with the optimization of the existing Cummins QG2800 generator system installed by the 2015-2016 senior design team. The implementation of both concepts should easily satisfy the project goals and constraints as described above by maximizing the efficiency of the existing components, while also collecting and storing as much external energy as possible.

3. Project Progress

As this project is a continuation from last year, the vehicle was given to Team 2 in the exact condition it was left by the last team. Team 2 has slightly differing project goals and therefore decided to take the system in a new direction by redesigning the overall circuitry, better implementing the installed generator, and through the addition of an external power source. Major progression milestones include improvements to wiring and hardware, completion of benchmark range testing, generator system modifications, and beginning the procurement process of our selected solar panel.

3.1 Wiring & Hardware Improvements

Team 2 completely scrapped and rewired the vehicle's overall circuitry to be in an operable condition as intended by last year's team to benchmark the current range of the vehicle before external sources were incorporated. The wiring is now more permanently housed and organized in a weatherproof box, protecting fragile electrical components and connections. Hardware improvements include a new installed LCD screen with several push buttons, allowing us to better interface between our electrical and mechanical systems. 3D-printed fan covers have also been fabricated and installed underneath the vehicle to protect the two power converters from water and dirt. Adjustments to the existing Arduino code that works with the system's microcontroller is ongoing, aimed at most efficiently controlling the distribution of power drawn through the system.

3.2 Benchmark Testing

To physically realize our project goal of an increase in the vehicle's range, the current range needed to be documented. The testing route was chosen based on having a varied duty cycle for the system to experience multiple periods of acceleration, deceleration, elevation changes, and complete stops. Two separate tests were performed to determine the theoretical range based on either battery or generator power alone. During the battery power test, the vehicle was recorded to consume approximately 710 kJ/mi and had a top speed of 25 mph. With the battery capacity calculated to be 15,840kJ, the theoretical range is 22.3 miles on battery power. During the generator test, the propane consumption rate of 0.271lb/mi was recorded. With our allotment of 20lb of propane, the theoretical range is 73.8 miles on generator power, combining for an overall benchmark range of approximately 96.1 miles.

3.3 Generator System Modification

Through inspection of the electric vehicle in its original state as given to Team 2, it was found that the additional Cummins QG2800 Generator shown in Figure 3 was not being utilized at its maximum efficiency. The previous system allowed for the vehicle to operate either on battery power or generator power alone, significantly decreasing the system's capabilities. The generator efficiency is maintained based on applying the maximum load that the generator can handle without it being overdrawn, causing the circuit to break. The condition that the system was received in, was set up in a way that while operating on generator power alone, not enough power was able to be supplied to the motor due to the max generator output of 2,800W. Also, while accelerating quickly, the system would overdraw the generator and cause the circuit breaker to be activated.

Figure 3. Cummins QG2800 Generator implemented on the electric vehicle.

Our implementation for the generator and battery tandem system is for the generator to always be running, simultaneously providing power in conjunction with the batteries to the motor while the vehicle is in use, reducing the rate at which the batteries are drained. While the vehicle is not in use, the generator will simply only supply power to the batteries, allowing for them to be charged. If the batteries were to reach a full charge, the generator would be then turned off as to not waste power. This system design insures that the vehicle is always running at maximum performance, while maximizing the efficiency in the power available. Team 2 has already implemented this system design into the vehicle circuitry through the use of two 100A Honeywell current sensors to record the current being drawn through the power converters. Also, a Digi-Pot Digital Potentiometer with 256 settings from 0 to 10kΩ has been integrated to work with the current sensors, allowing us to set how much voltage is being drawn, ensuring that the cutoff limit of 2,800W is not surpassed and that the generator maintains maximum efficiency. A sizeable efficiency increase should be easily obtained through this circuity reconfiguration. By always operating the generator at maximum load, the loss of energy being converted from propane to electricity to mechanical motion is minimized, and our range will ultimately be extended.

3.4 Solar Panel Selection

After extensive research was conducted, a few options of solar panels were considered. The size, installation method, price, and control of the panel were all taken into consideration. Team 2 has selected a 280W solar roof replacement kit that will be manufactured specifically to fit our existing frame. The kit is being purchased from *Solar EV Systems*, a company specializing in solar panels designed for small electric vehicles and golf carts. Figure 4 below represents an example of the solar roof replacement that will be installed on our vehicle. The kit includes the solar roof panel, an MPPT charge controller, and all necessary electrical connections and mounting hardware for easy integration and installation. The digital MPPT charge controller has an efficiency of 97% and will be utilized by the photovoltaic array once connected to charge the vehicle's batteries as needed. The controller gives the user full control over how much power is being delivered from the solar panel to the batteries, and protects the panel from any backflow of electricity. The solar panel is predicted to increase the range of the vehicle by at least 10 to 15 miles. We are currently in the procurement process of the kit, just having received the final quote of $1,550 after sending the company our specific frame measurements.

Figure 4. Example of an electric vehicle with solar replacement roof.

4. Challenges

In an ideal situation, this project will go by smoothly, and we would not have any problems occur while trying to achieve our ultimate goal. Unfortunately, that is not the case for most projects, and challenges and problems will be encountered at some point. Some of these problems could be anticipated but unexpected challenges could arise.

One of the main challenges that will occur is maintaining and protecting the battery life cycle. This will affect the overall performance, efficiency, and range of the vehicle. The testing conditions for the vehicle is another challenge that will be encountered soon. Replicating a suitable surrounding such as a plain, smooth terrain to test the speed and range of the vehicle will have to be done to ensure good test results. Another main challenge that has been encountered already is coding the microcontroller. Having a reliable running code for the microcontroller is essential to interface between our power sources for the vehicle. Circuitry design is also another challenge to be overcome as to ensure that all electrical components are not damaged, or “fried” through the improper flow of electricity. And finally, the team could run into procurement process delays of essential components and anticipates that this will probably occur; therefore, we have allotted ample time in our schedule for this process.

5. Project Planning

In order to ensure that the project be completed in a timely manner, a schedule had to be developed. This schedule can be seen on the following page in Figure 5 in the form of a Gantt chart. The schedule includes our main areas of focus, including a large amount of early time being allowed for the solar kit and necessary electrical components to be procured and installed. Once completed, we will begin testing to in order to calculate and document the amount of range increase that attributes from the both the solar panel and the generator system modification. We have then left ourselves with approximately a month for final design iterations and testing before we conduct our final calculations and documentation. Our project is set to be completed by April 13th, 2017 as this is the day of our final presentation. All team members will be involved in these tasks, utilizing the skills from both of our mechanical and electrical engineering disciplines as effectively as possible.

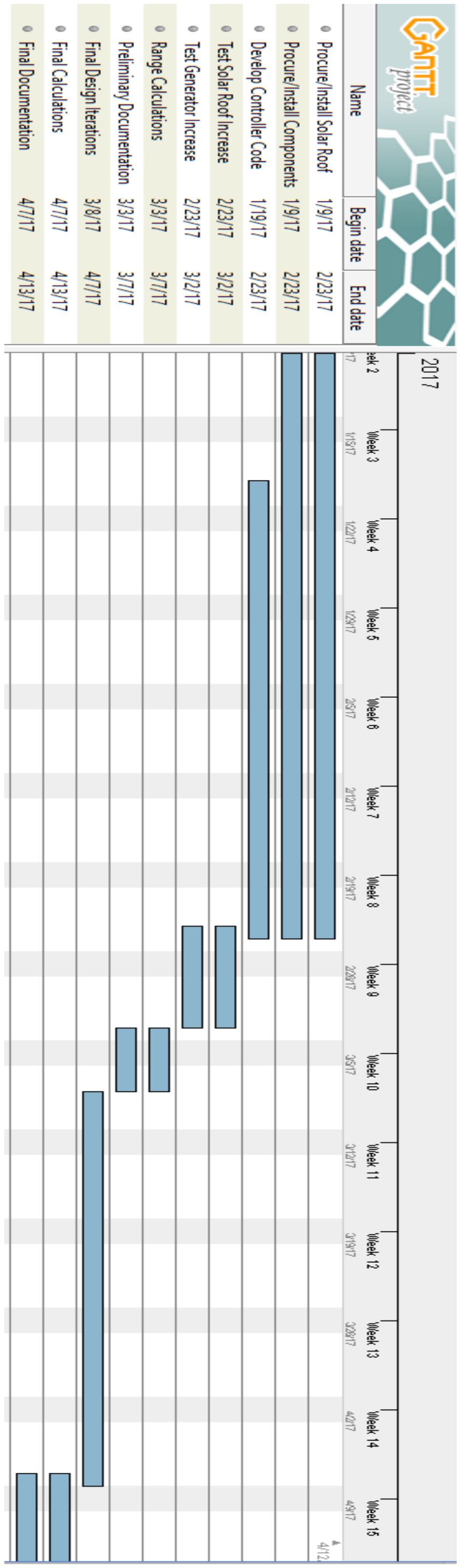

Figure 5. A Gantt chart was developed to easily illustrate and organize our project schedule over the spring semester.

6. Project Summary

Team 2 was tasked with finding creative ways to extend the range of an electric vehicle by 15% without decreasing the top speed or acceleration rate by more than 10%. Based on the needs assessment, Team 2 used various engineering design methods to produce and select the best concepts to implement. The team is currently in the process of procuring our 280W solar roof replacement kit as our external power source and has completed several project progression milestones. These include wiring and hardware improvements, benchmark range testing, and the implementation of our proposed generator system modification. Moving forward, installation of the necessary components and further testing and design iterations are to be completed. Team 2 is optimistic that our project goals and constraints will be satisfied by our due date of April 13th, 2017 by following the project schedule laid out above.

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