Midterm I Report

Team 2

Electric Vehicle Range Extension

Members:

Taofeek Akintola (taofeek1.akintola)

Sean Casey (spc13d)

Khaled Farhat (kf14d)

Luke Marshall (lsm13b)

Seth Rejda (slr13b)

Hafs Sakka (hos12)

Faculty Advisor

Dr. Seungyong Hahn

Sponsor

Dr. Michael Hays

Instructors

Dr. Nikhil Gupta, Dr. Chiang Shih

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ABSTRACT

Team 2 is working with sponsor Dr. Michael Hays from Cummins, Inc. and faculty advisor Dr. Seungyong Hahn in order to improve the range of an electric vehicle using alternative power adders. The sponsor specifically asked Team 2 to research solar panels and regenerative braking. Upon doing so, Team 2 is considering implementing both options but is also exploring other creative options for recharging the batteries and reducing power usage while the cart is in use. Team 2 has determined the needs from the sponsor and must begin testing in order to know the current range of the cart so that it may be extended by the necessary 15% without significant decrease in acceleration or top speed. Also, Team 2 is not allowed to change the amount of fuel supply. Moving forward, Team 2 must first get last year's project to work by making minor adjustments to wiring and code. Once complete, Team 2 will need to finalize options for increasing the range and then implement those options to obtain our ultimate goal.

1. Introduction

The purpose of this project is to improve the overall range of the electric vehicle by at least 15% of what was intended to be achieved from last year. Team 2 is hoping to focus on adding additional power sources, finding ways to generate power while in motion, improving the overall electric system, and reducing the weight in order to ensure that all aspects of the vehicle attribute to the range improvement. The sponsor has instructed that we begin by getting the vehicle to function properly, in order to begin testing its current range. So far, the team has been working on solving the problems from last year, which is for the generator and battery tandem system to work together properly. As the batteries deplete and the generator turns on, the batteries should start to recharge themselves and keep charging until they reach capacity in order for the generator to turn off. So far the vehicle has been having problems achieving that goal as the generator continues to run when the batteries are fully charged. Essentially In order to begin to document and test the current range of the vehicle, that problem needs to be solved. Once solved, then data will be recorded and used as a benchmark in order to see how further improvements can be made.

2. Project Definition

2.1 Background Research

2.1.1 Photovoltaics

There has always been a great effort in finding out new methods to generate energy; one of the most significant and widely used methods is solar panels. Solar energy is an important renewable source for heat and energy. The sun generates energy from a process called nuclear fusion, and this energy can be captured, transformed, and stored as electrical energy using solar panels. Currently, solar roofs are manufactured for installation on carts similar to the one used by our team. Solar companies claim their solar cart roofs generate anywhere from 45 watts to 360 watts, depending on cost. Large solar roofs are 6ft by 4ft and weigh about 80lbs which could cause an issue in performance of our vehicle due to increased weight. There is a maximum theoretical efficiency of solar panels based on the amount of solar radiation that hits the earth’s surface. On a sunny day at the equator there is a solar radiation density of about 1000W/m2. It is assumed that actual power generation will be less than the solar companies claim; however, an accredited source noted a noticeable increase in a carts range to the addition of a solar power source.

2.1.2 Drag Reduction

To increase the range of the vehicle, the team needs to determine under what conditions the vehicle will drain energy the most. For long distance continuous travel, it is known that the largest friction force and loss of energy is wind resistance. If wind resistance and friction could be eliminated theoretically the cart could coast forever. This is impossible, though it is possible to roughly determine the cart’s coefficient of drag which would help us benchmark the cart’s aerodynamics and with the help of Dr. Hahn, reduce the coefficient of drag. Drag can also be reduced by making sure the cart is properly maintained. Lubrication of the joints and gearing with grease and oil will reduce the drag associated with the cart’s mechanical power transfer systems. Proper inflation of tires is also a simple fix and can greatly affect the cart’s range.

2.1.3 Regenerative Braking

Regenerative braking converts the vehicle's kinetic energy back into electrical energy to be stored in the batteries when the operator decides to slow the vehicle down, this system is most commonly known due to the Toyota Prius and is ideal for stop and go driving environments. Many new high-end carts come with regenerative braking systems installed, it is believed that ours does not; however, complete regenerative braking kits can be purchased for installation in our vehicle. A new motor may need to be purchased because some older motors are not compatible with regenerative braking addition kits. The amount of energy converted by a regenerative braking kit is easily calculated through the change in kinetic energy.

2.1.4 Geographic Regeneration

Based on the main goal for this project, the team is expected to be as creative as possible, that means getting out of the box when trying to supply the vehicle with additional power to meet the 15% increase in range. During one of the brainstorming sessions with our advisor Dr. Hahn, he introduced the idea of capturing some energy as the vehicle is driving downhill. Based on the vehicle’s weight, an angle between the body of the vehicle and the surface it is being driven on should be determined, and for any angle that is equal or greater than that value, the vehicle should be able to keep moving while generating some energy into the batteries.

2.2 Need Statement

Our team has been 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. The project’s sponsor requires 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 has been 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.”

2.3 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:

- Document current vehicle performance
- Research variety of possible power adders
- Procure/incorporate additional sources
- Reconfigure overall vehicle circuitry
- Increase vehicle range by 15%

2.4 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%

2.5 Current Project Status

This vehicle is a continuation project from last year. The cart was given to Team 2 this year in the condition it was left by last year's team. The previous team was attempting to have a generator power the electric vehicle and recharge the batteries once they were depleted to a certain percentage of their full charge. They were unable to finish their segment of the project in that the generator would work in tandem with the batteries but it would turn on before the appropriate time. Team 2 is now attempting to mitigate the errors by making adjustments to the code and wiring system used to determine the charge left in the batteries and turn on the generator appropriately. Instead of measuring the voltage drop associated with running the electric vehicle, Team 2 is attempting to use a current sensor to measure the loss of power over time and then allow the generator to turn on and power the system. After this is completed, Team 2 will measure the range of the vehicle by both physically testing the system and by doing theoretical calculations based on the power consumption from both the batteries and the generator as they relate to a known distance. To date, Team 2 has worked on rewiring the circuit of the electric vehicle and adding the current sensor so that the current can be measured. Also, the Team is working on making adjustments to the Arduino code so that it will continually measure and record the power used so that the generator can be appropriately used in tandem with the battery system. Research is being conducted to see which systems can be used to achieve a 15% increase in range while also fitting into the aforementioned constraints.

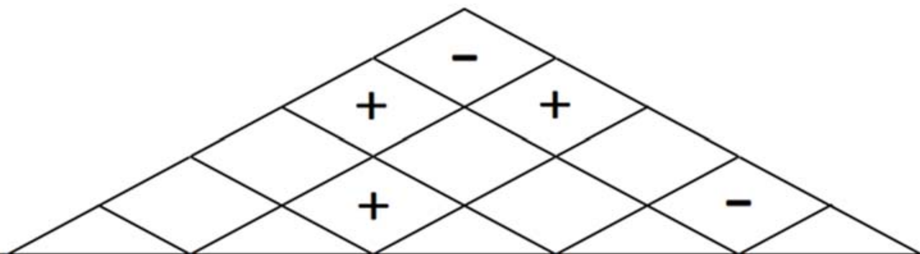
2.5.1 Generator-Charger System Control

Last year’s team spent a great deal of time and effort developing a new charging system that ran off of an onboard microcontroller which records values for the various sensors and then implements control over the components. This allows for the generator, a Cummins QG2800, to turn on automatically when needed and off when the batteries are recharged. It also controlled when the battery warmers would turn on and off. The generator can be seen below in Figure 1. The goals of this year’s project vary slightly from that of the previous year in that operating in extreme conditions is no longer a requirement. It is also important to note that the code in its current state does not operate the generator correctly. Bearing that in mind team 2 has two primary options for proceeding with the project. The code and microcontroller selected and produced by last year’s team can either be modified to the new requirements or a new code and controller can be selected.

Figure 1: Last year’s team decided on utilizing the Cummins QG2800 Generator

3. Preliminary Design

3.1 House of Quality (HOQ)



CR \ EC	Efficiency	Safety	Durability	Power	Weight
Reliability	2	3	4	1	0
Performance	5	1	2	5	2
Cost	4	2	4	4	0
Capacity	1	1	2	1	2
Range	5	1	3	5	3
Total	17	8	15	16	7
Rank	1	4	3	2	5

Figure 2: House of Quality diagram illustrating the relationships between our customer requirements and engineering characteristics.

This House of Quality was developed using our needs assessment and from earlier discussions Team 2 conducted with both our sponsor and faculty advisor. The customer requirements directly correspond to various constraints of the project such as the range, which must be increased by 15%, and the performance, which must not be decreased by 10% for either top speed or acceleration. As for the engineering characteristics, Team 2 determined efficiency, durability and power were the most important by comparing and contrasting to the customer requirements. Efficiency is key to this project because it is through having an efficient system that the range of an electric vehicle will be increased. Power is the second most important characteristic for the reason that the top speed and acceleration of the electric vehicle may not be decreased by 10%. Durability is also important because the added components need to be able to withstand the operating conditions of an electric vehicle which include but are not limited to bumpy terrain, inclement weather conditions, rain, dirt, and dust. These are basic conditions which may be met by any electric vehicle, especially the cart on which these components will be implemented and tested.

3.2 Concept Generation

The main design aspect for this project deals with the creativity and implementation of an additional power source. For that reason, the following design ideas for this source were developed.

3.2.1 Photovoltaic Method

As mentioned earlier, solar panels are becoming ever popular in a multitude of applications. They have already been put into practice on electric vehicles with great results, some sources claiming as much as a 25% increase in range. There are various solar panels for this application. Figure 3 shows an example of a solar panel roof for an electric vehicle.

Figure 3: Electric Vehicle showing an example of a solar roof installed.

A full solar panel roof can produce between 100 and 300 watts for a standard size electric vehicle which is approximately 1.2 x 0.9 m. It is important to note that this project is based out of Florida, where the solar panel will operate in near optimal conditions with the abundance of sunlight year-round. The system has many advantages including being lightweight and being available in many different formats. Options include having a full roof replacement solar panel which serves as both a power adder and the roof of the electric vehicle. There are also flexible solar panel mats which simply secure to the preexisting roof. All versions are simple to install and require no special tools. The greatest drawback is the price. For durable solar panels for an electric vehicle, the price ranges between $600 for a low end system to upwards of $2500 for a very efficient system. If solar panels are used then some time will need to be spent in determining the best option to achieve maximum power output per dollar spent.

3.2.2 Regenerative Braking Method

This method is already implemented in electric vehicles and utilizes the motor to provide power back into the system. The motor is back-driven instead of using the brakes to slow down, which allows for energy to be returned to the batteries instead of being wasted. The life of the brake pads is extended as a result which reduces overall maintenance costs for the electric vehicle. The drawbacks for this method include price. A typical regenerative braking system can cost well over $2000. It also requires a great deal of work to install and it is not the most efficient means of putting energy back into the batteries of an electric vehicle as it only stores and replaces a small fraction of the energy that was needed to move the electric vehicle.

3.2.3 Geographic Regeneration Method

This idea involves using the landscape and a gyroscope in order to cut off power to the motor when the electric vehicle is able to coast on its own and use a similar system to regenerative braking in order to store energy by back-driving the motor. The same problem of cost and difficulties that occur with regenerative braking also arise here. This method also has the added difficulty of properly coding and accounting for all circumstances in which power might be needed despite the electric vehicle satisfying the angle which would cut the power to the motor. This option does have the benefit that it can be used without necessarily implementing regeneration such that range can be increased simply by cutting power from the motor whenever necessary, allowing for a small increase in range through conserving power. It is also relatively simple in that case and can be implemented in conjunction with one of the two previously mentioned options. There are very few specifications to consider with this option as the performance varies with each system.

3.2.4 Wind Turbine Generation Method

Wind generation has been heavily explored in recent years but it is not yet implemented in the realm of electric vehicles. The idea is to have multiple small wind turbines mounted to the body of the electric vehicle which would allow for power to be generated as the vehicle moves. This concept is heavily theoretical and may be considered in the case of a golf cart because it already experiences significant drag from its box like shape. Therefore, the power gained from the turbines may end up being negligible due to the increased drag. Difficulties with this option include that the increase in range may be negligible, and it is also unknown how difficult or costly such a design could be.

3.3 Concept Evaluation and Selection

3.3.1 Selection Criteria

At this point in the project, Team 2 has come to a preliminary decision on which method would be most appropriate to achieve the goals outlined in the aforementioned goal statement. The sponsor, Dr. Hays, has asked us to continue researching other, more interesting methods throughout the rest of this semester and to consider implementation at a later date. After a great deal of consideration and analysis of the project goals, constraints and customer requirements, Team 2 has determined that the primary selection criteria are cost, performance, reliability, and ease of implementation.

- **Cost:** Although the budget for this project is somewhat flexible and the cost is not considered a constraint, it is still important to consider. It is good practice to choose the most cost effective option that will meet all of the requirements, constraints and goals outlined for the project.
- **Performance:** As previously mentioned, the car needs to operate with as little reduction in performance as possible while still meeting the increase in range. To make this happen, the performance of each new power adder must be considered to ensure that it will not inhibit the performance of the electric vehicle.
- **Reliability:** This criterion is crucial to the project as the components must consistently work together without failing in order for the project to be considered a success. It is essential for design and implementation of the power adders to be robust.

- **Ease of Implementation:** For the time constraints of this project, it is best to keep in mind the simplicity of the solutions.

3.3.2 Pugh Decision Matrix

According to the selection criteria, a Pugh decision matrix was utilized to determine the best design options when compared across each other with weighted values. It was determined that performance and ease of implementation were the most important criteria followed by reliability and finally cost.

Criteria	**Weight**	**Photovoltaic Method**	**Regenerative Braking**	**Geographic Regeneration**	**Wind Turbines**
Cost	1	1	1	2	2
Performance	3	3	1	2	1
Reliability	2	3	3	1	1
Ease of Implementation	3	3	2	2	1
Total		**25**	**16**	**16**	**10**

Figure 4: A Pugh decision matrix was developed to compare design options.

Based off of the weighted design criteria, the photovoltaic method of generating external power was determined to be the optimal choice for Team 2. This method is very easy to implement into the electric vehicle circuitry and hardware and will produce a reliable range increase due to being highly efficient. Regenerative braking and the similar geographic regeneration method placed second as both are harder to implement into our platform and won't perform quite as well. The wind turbine generation method placed last as this idea would require several components and produce the least amount of added power.

3.3.3 Conceptual Design

After using engineering design methods for decision making, Team 2 was able to produce a preliminary design. First, Team 2 will use last year's microcontroller and wiring with minor adjustments to include the additional power adders. The solar panel option was selected for its ease of implementation, cost, and performance. The solar panel should provide enough power to reach the 15% increase in range. However, if time and resources permit, Team 2 would like to consider various aspects of the geographic regeneration idea, such as cutting/limiting power when moving downhill and implementing a regenerative braking system. The completed generic system as it pertains to electric vehicles is shown in Figure 5. The overall system consists of a microcontroller that controls the generator and it's interaction with external power sources and to the electric vehicle itself.

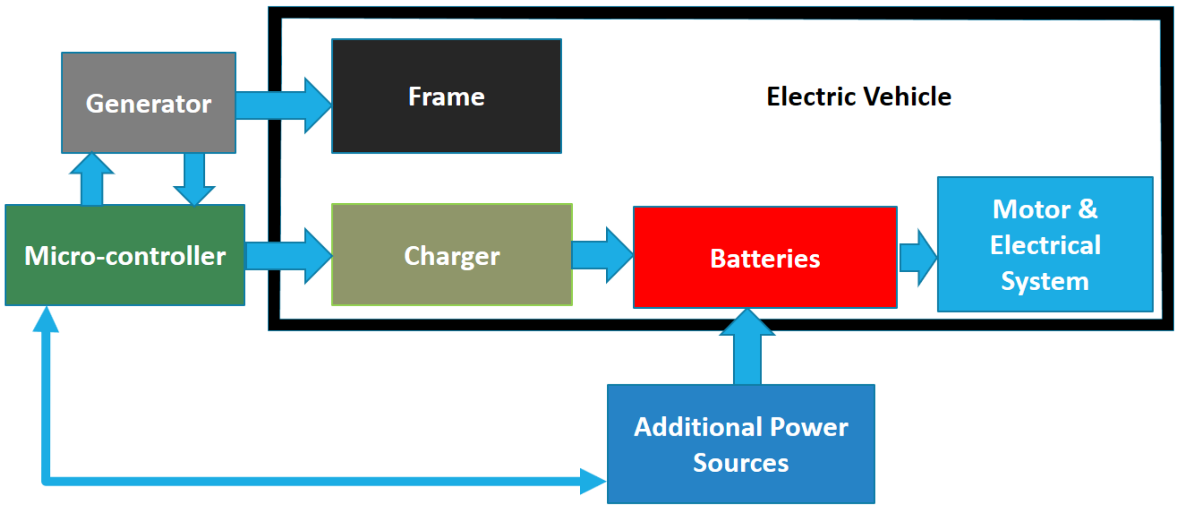


Figure 5: General system schematic showing the various components and their interactions with the electric vehicle.

4. Challenges and Risks

In an ideal situation, this project will go by really smoothly, and we would not have any problems occur while trying to achieve our 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. A popular adage of this is Murphy's Law, which states “Whatever can go wrong, will go wrong."

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. Finding a suitable surrounding such as a plain, smooth terrain to test the speed and range of the vehicle will not be easy. Another main challenge that has been encountered already is coding the microcontroller. Having a reliable running code for the microcontroller will help to interface between our power sources for the vehicle. This is going to be one of our utmost challenges that we need to tackle.

Circuit arrangement and organization is also very important. Soldering and fixing the circuit to the vehicle after it has been tested successfully is essential. This will prevent components from falling out of place when the vehicle is in motion or on rough terrain. Installing a suitable case for the circuit and the microcontroller is a must in order to protect it from most weather conditions.

Working on the vehicle itself and having these challenges occur on our way to achieving the ultimate goal will itself expose the overall outcome of the project to risks. Some of the excepted risks are causing damage to the batteries or frying electrical components. The batteries can be damaged if they are drained below the minimum voltage. This can happen when the power source that is supposed to charge up the battery fails due to interfacing codes in the microcontroller. The risk of frying the microcontroller is a great concern. Damages to the microcontroller can occur when the excess voltage is sent to it. The risk of accidents causing injuries to team members or pedestrians is also an issue that must be kept in mind.

5. Project Planning

5.1 Schedule

In order to ensure that the project be completed in a timely manner, a schedule had to be developed. This schedule can be seen below in Figure 6 in the form of a Gantt chart. The schedule includes our main areas of focus, including a large amount of early time being spent on brainstorming and research and the latter part of the semester being spent on coding, ordering parts, and testing.

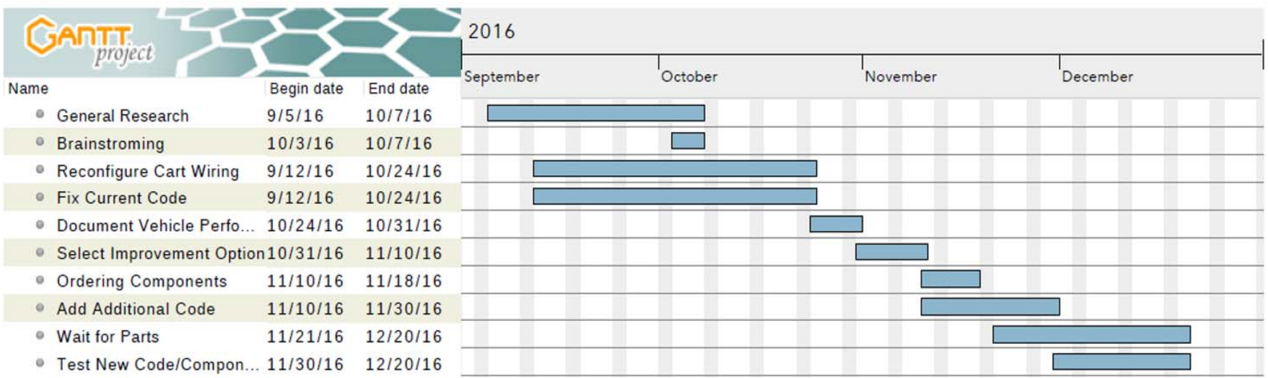


Figure 6: A Gantt chart was developed to easily illustrate and organize our project schedule over the first semester.

5.2 Resource Allocation

Team members and their respective project roles have been broken down into the following list.

- **Taofeek Akintola:** Responsible for calculations on theoretical available energy and corresponding range for each external power source option. Taofeek is also the electronics specialist for the team.
- **Khaled Farhat:** Responsible for creating system circuit diagrams and indicating typical current flow at maximum load. Responsible for researching needed circuit components. Khaled is also the lead EE and is in charge of maintaining the overall electrical system of the vehicle.
- **Hafs Sakka:** Responsible for making sure the vehicle is maintained and properly lubricated. Responsible for reducing vehicle’s weight without reducing comfort or convenience. Hafs is also the team's webmaster, which includes designing the website and uploading/updating all relevant information to it.

- **Seth Rejda:** Responsible for researching the best solar panel option and identifying other cost effective ways to increase the fuel economy. Seth is also the team leader and project manager.
- **Luke Marshall:** Responsible for equipping the vehicle with the proper current sensing hardware and wiring for design implementation. Luke is the lead ME for the team.
- **Sean Casey:** Responsible for coding the controller to display necessary data and have proper operation of the vehicle. Sean is also the team treasurer.

6. Conclusion

Team 2 was tasked with finding creative ways to extend the range of an electric vehicle by 15% without dropping the top speed or acceleration rate by more than 10%. Based on the needs assessment, Team 2 used various design methods to produce engineering characteristics and customer constraints which resulted in the design selection criteria that was used to finalize a preliminary design option for the project. The design as discussed above, will use the generator and microcontroller installed from last year’s team with minor modifications. Team 2 is also planning on implementing solar panels and possibly geographic regeneration in order to meet the goals set forth by the sponsor. Moving forward, Team 2 will complete various tests to implement and document the range before and after the new components are added.

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