Electric Vehicle Range Extension

Team 2

MEMBERS: SETH REJDA, HAFS SAKKA, TAOFEEK AKINTOLA, KHALED FARHAT, LUKE MARSHALL

ADVISER: DR. CHIANG SHIH

SPONSOR: DR. MICHAEL HAYS

Presentation Overview

- Background
- Project Scope
- Project Progression
- Results
- Summary

Project Overview

Cummins, Inc. & Electrical Power System Performance

- Advanced Batteries
- Upgraded Electronics
- Efficient Generators
- Non-Traditional Power Adding Methods

Tasked with extending the range of an electric vehicle

- Tomberlin 48V Electric Low Speed Vehicle
  - Six – 8V Lead/Acid Batteries
  - Additional Generator (2016 Project)
  - Max Speed: 25mph

Figure 1. Provided Tomberlin Electric Vehicle

Project Scope

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 Initial vehicle performance
- Research/incorporate additional power sources
- Finalize overall system circuitry
- Test/document increase in vehicle range

Constraints

- Fuel supply cannot be increased
- Vehicle must be able to carry 4 people
- Top speed cannot be reduced by more than 10%
- Acceleration cannot be reduced by more than 10%

Motivation

- Rising cost of clean fossil fuels
- Effort to reduce carbon emission due to conventional fossil fuel usage
- Increasing use of mass transportation
- Need for renewable energy integration

Background

Previous Project Overview

- Received electric vehicle in factory condition
- Different goals/constraints
- Added Cummins QG2800 Propane Generator

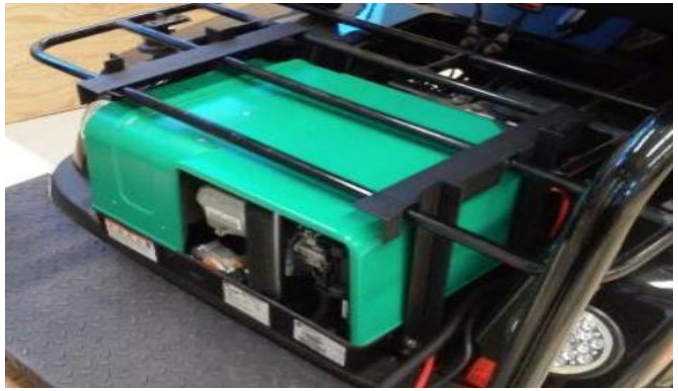

Figure 2. Generator Location

Initial Condition

- Wires left unlabeled and unmounted
- Microcontroller code not running properly
- The Vehicle only runs on one power source at a time

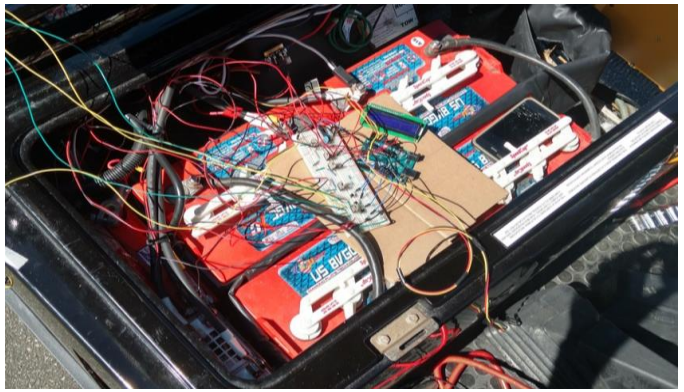

Figure 3. Initial wiring condition

Initial Improvements

- Label and mount the wires
- Adding Current sensors
- Calibrating current sensors
- Create a code that records data
- Inflate the tires

Figure 5. Current Sensor

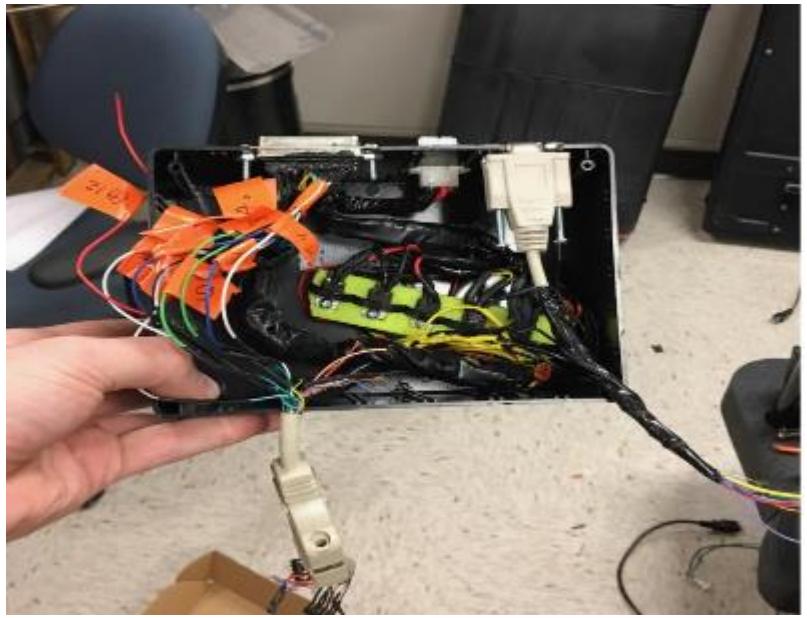

Figure 4. Labeled and mounted wiring

Benchmark Test Results

Battery Power Alone

- Range: 24.8 miles
- Speed: 25 mph
- Consumption: 710 kJ/mile

Generator Power Alone

- Range: 73.8 miles
- Speed: 8 mph
- Consumption: 0.271 lbs/mile

- **Theoretical Range: 98.6 miles**

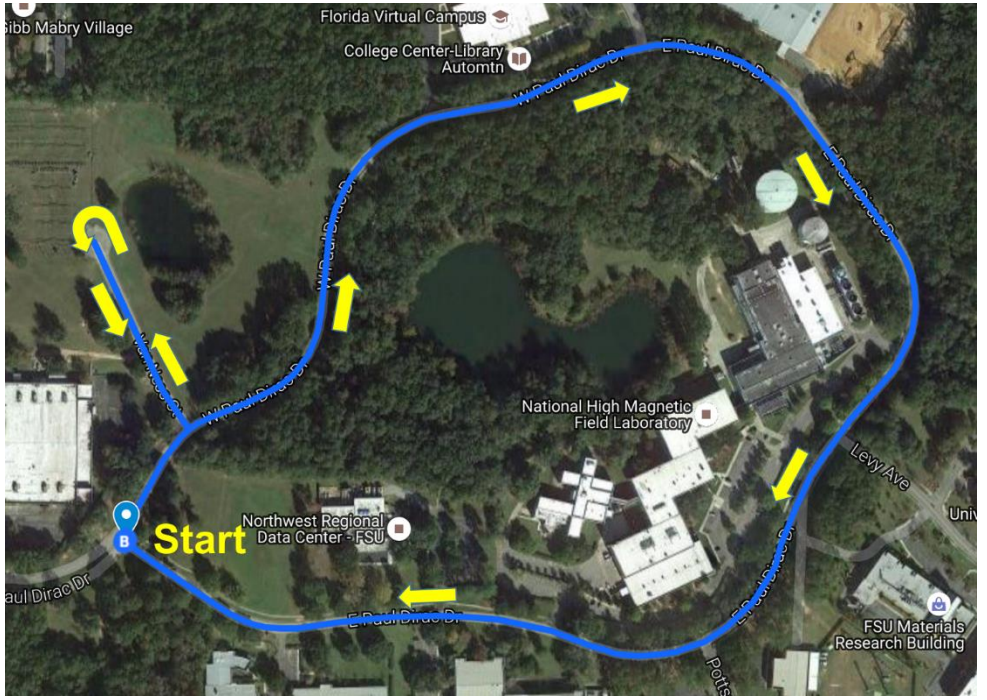

Figure 6. Selected Testing Track

Concept Generation

Table A. Methods of implementation

Researched ideas	Cost of implementing	Advantages	Constraints
Solar Panel	Within budget range	Vast Amount of sunlight in Florida	Shading, Dust
Regenerative braking	Out-of budget	Reuse the power lost due to braking	Must be used with A.C motor
Generator Optimization	Within budget range	Maximizing the efficiency of the Generator	Hard to implement

Decision Matrix

Table B. Decision Matrix

Criteria	Weight	Photovoltaic Method	Regenerative Braking	Generator Optimization
Cost	1	**1**	1	**3**
Performance	3	**2**	1	**3**
Reliability	2	**3**	3	**3**
Ease of Implementation	3	**3**	1	**1**
Total		**22**	13	**21**

Benchmark Conclusions

- Unsatisfactory delivery of power from the generator to the motor
- The Generator not performing at maximum efficiency
- Motor requires a lot of power
- Generator alone does not provide enough power due to maintain top speed
- Based on the Measured consumption rate, the overall range was determined

Generator System Modification

Original System

- Runs on generator or battery power
- Idled during breaking or coasting
- Occasionally overloaded gen
- Ran at reduced speed on gen power

New System

- Generator continually operates at max efficiency
- Motor is constantly supplied necessary amperage
  - No loss in performance
- More difficult to implement

Figure 7. Cummins QG2800 Generator

Generator System Modifications

- Contacted battery manufacturer
  - Determined maximum charging rate (100A)
  - Noted maximum operating temperature (120°F)
  - Discussed suitability for hybrid design
- Created Charge Controller
  - Prevents generator overload
  - Allows batteries to charge while motor is running
  - Regulates converter output voltage
    - digital potentiometer
    - current sensors
    - Arduino

Figure 8. US 8VGC Battery

Solar Panel Selection

280W Solar Roof Replacement Kit

- Manufactured by *Solar EV Systems* to vehicle specs
- Includes integrated 97% efficient charge controller
- Adds approximately 0.58 - 1.42 miles per hour of run time depending on shading
- 72 in x 47 in x 3 in
- Weight: 65 lbs
- Cost: $1,550

Figure 9. Solar roof replacement example

System Diagram

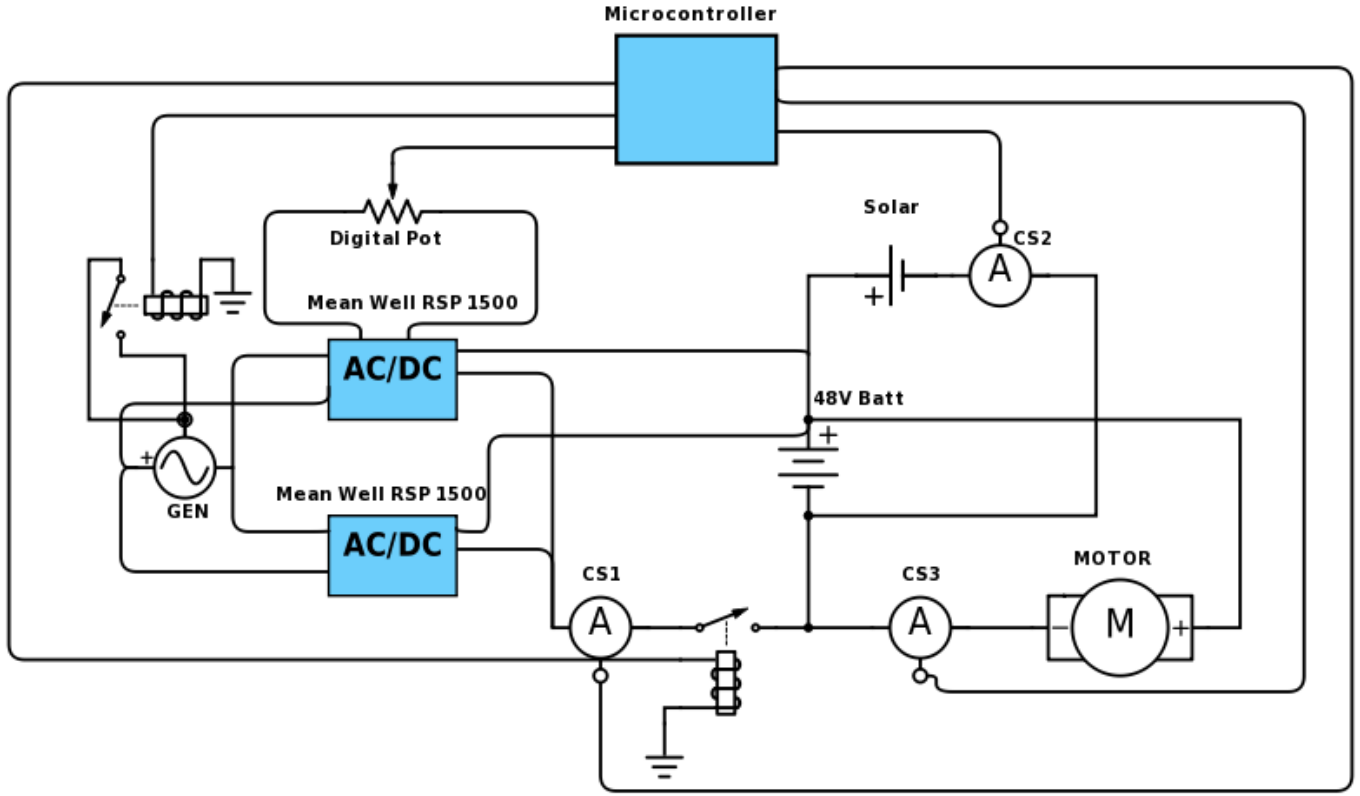

Figure 10. Overall System Diagram

Pre testing Predicted Range Increase

- Battery Capacity
  - Assuming only 60% usable power
  - **17.6 MJ**
- Generator Capacity
  - Assuming 1 operable AC/DC converter
  - **61.7 MJ**
- Solar Panel Capacity
  - Assuming 6 hours of sunlight
  - **5.4 MJ**

Source	Energy Capacity (MJ)
Batteries	17.6
Generator	61.7
Solar Panel	5.4
Total	**84.7**

Theoretical Range & Increase

- (84.7 MJ)/(0.71 MJ/mile) = **119.3 miles**
- (119.3 - 98.6)/(98.6) = **21.0% increase**

Post Testing Actual Range Increase

- Battery Capacity
  - Assuming only 60% usable power
  - **17.6 MJ**
- Generator Capacity
  - 2 operable converters
  - **68.0 MJ**
- Solar Panel Capacity
  - Assuming 6 hours of sunlight
  - ~60% shade → 120W of 280W
  - **2.6 MJ**

Source	Energy Capacity (MJ)
Batteries	17.6
Generator	68.0
Solar Panel	2.6
Total	**88.2**

Calculated Range Increase

- (88.2 MJ)/(0.71 MJ/mile) = **124.2 miles**
- (124.2 - 98.6)/(98.6) = **26.0% increase**

Project Budget

- **Total: $2,300**
  - Original: $2,000

- Electrical Components
  - $553
- Solar Roof Kit
  - $1,550
- Remaining Amount
  - $197

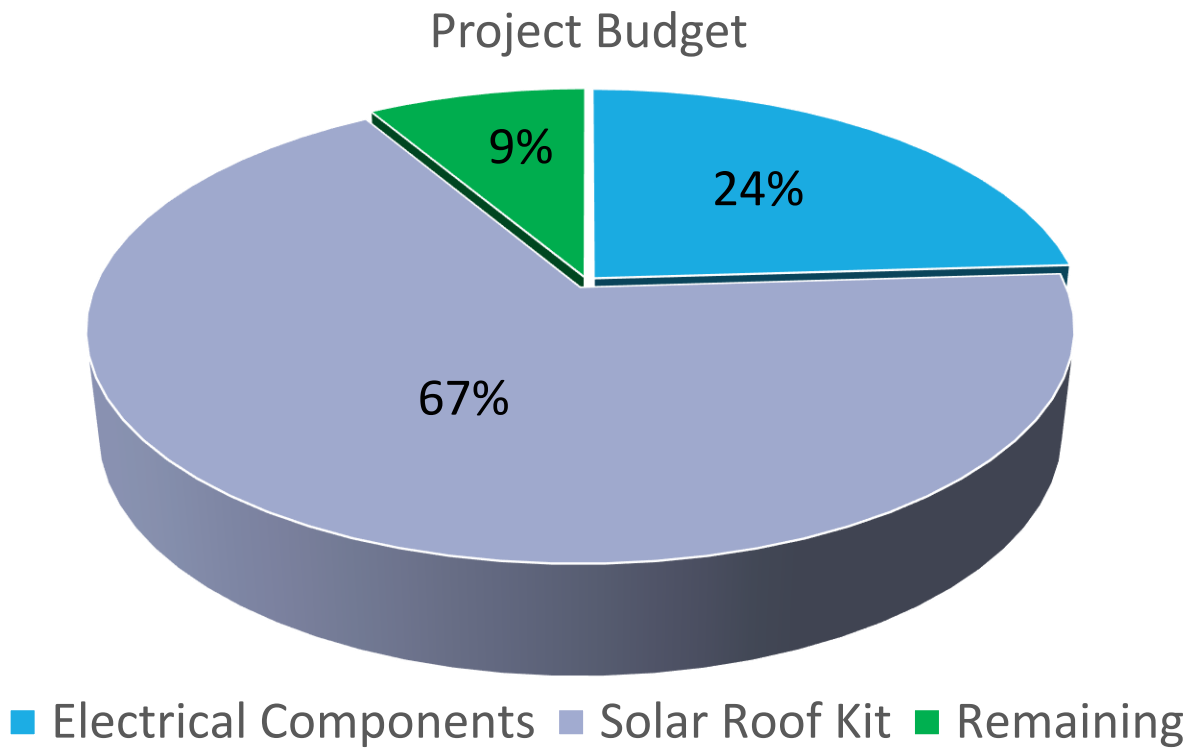

Figure 11. Pie chart illustrating budget use

Challenges Faced

- Making original system operable
- Protecting electrical components
- Overall system circuitry design
- Budget extension
- Procurement process delays

Progress Summary

- Initial Improvements
  - Wiring/hardware improvements
- Benchmark Testing
- Concept Generation & Selection
- Design Implementation
  - Generator system modified
  - Solar roof/electrical components installed
- Predicted Results
- Final Testing Results
  - A 26% total range increase met
  - Top Speed and acceleration not altered

Figure 12. Final Design

Project Summary (Expand on/re-do)

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."

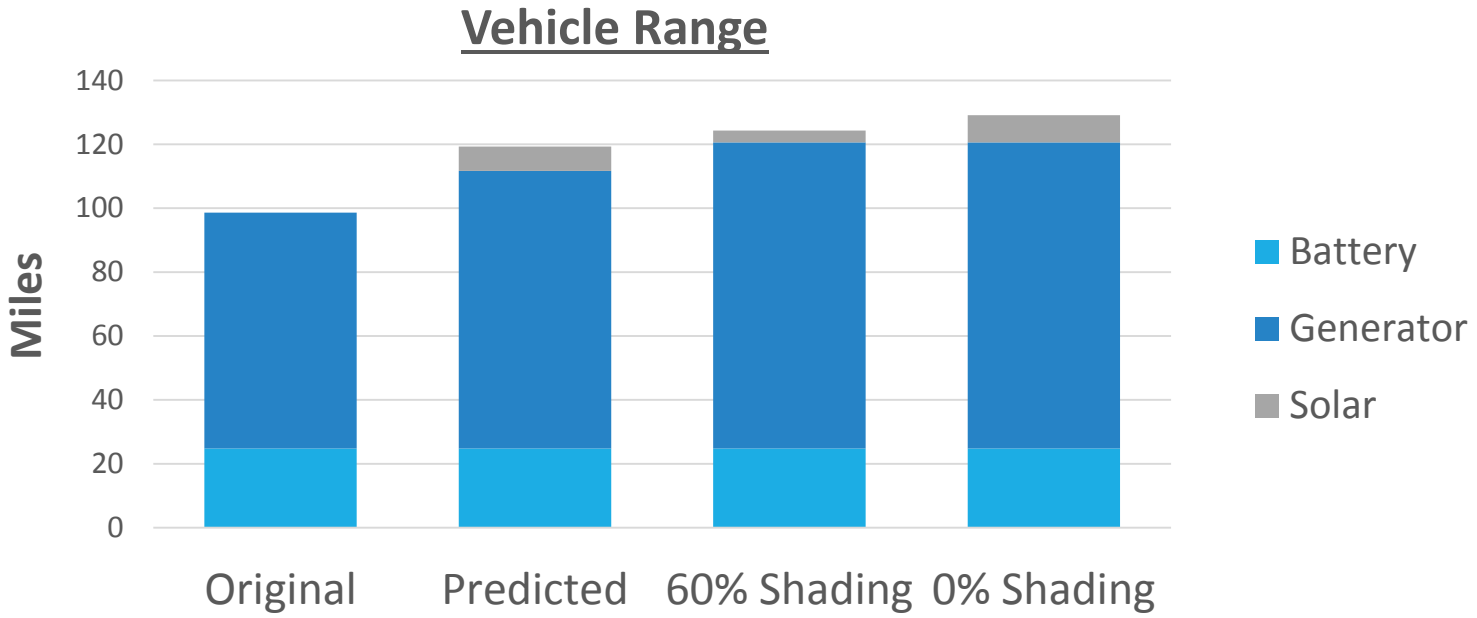

Figure 13. Vehicles Performance

Future Work

- Incorporate more non-traditional power sources
- Replace existing lead-acid batteries with better ones
- Replace existing frame with ultra-light materials
- Add more user interface capabilities

Figure 14. New reduced frame example

References

[1] “Battery University" in BU-403: Charging Lead Acid. [Online].

[2] "Product specs," Solar EV Systems - Solar Golf Carts, Roof, Tops, Solar Panel LSV Cart Kit for EZGO, Club Car, STAR, Yamaha, Bad Boy. [Online].

[3] "How to charge sealed lead acid batteries," in Power Stream, 2000. [Online].

[4] "RV generator set Quiet Gasoline TM Series RV QG 28 00," in Cummins Onan Specification Sheet. [Online].