Team America

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1 Introduction

The search for sustainable energy in a world where we are depleting natural resources has led to the development of systems that have made automobiles run on less, or no gasoline at all. Hybrid cars have the capability of combining the power of internal combustion engines and electric motors to substantially increase the efficiency of the vehicle, and electric cars are able to run entirely off of batteries and eliminate the need for any other fuel. However, both systems involve batteries that have finite and fairly short life times. A hybrid electric vehicle that is capable of powering an electric motor using a bank of ultra-capacitors would avoid the problems of short lifetimes and recharging batteries.

2 Problem Statement and Proposed Solution

Dr. Bauer is currently working on and researching a hybrid electric vehicle. The vehicle is a truck that runs an electric motor off a bank of ultracapacitors. A crude system is currently in place to charge the ultracapacitors using a diesel generator. Our task is to develop a more robust and intelligent charging system for the ultracapacitors that aids research activities, has a human to charging system interface, and uses the current charging system as a starting point.

The new charging system will use the current generator system, bank of ultracapacitors, transformer, and bridge rectifier circuitry. The old control circuitry, using MOSFET drivers to turn the generator on and off, will be replaced with solid state relays accepting signals from a new microcontroller and being powered by the 12 volt generator battery. The solid state relays will be more robust than the old MOSFET circuitry by virtue of its higher current ratings and simpler circuit design. Current, temperature, and voltage sensors will be used where appropriate to aid in decision-making for turning on and off key system components.

A key differentiation between this charging system and the old charging system are the additions of a global positioning system (GPS), display screen, keyboard, and SD card. The SD card allows for data storage of pertinent system values, such as ultracapacitor charging time, current draw by the truck motors at different points in time and under different driving conditions, as well as ultracapacitor voltage levels at different points in time and under different driving conditions. The GPS system, when interfaced with the microcontroller, will allow us to compute and predict energy needs for the vehicle. The display screen and keyboard will allow the user to access the system data saved on the SD card and can also display important system values such as speed of the vehicle, the amount of miles expected to be available in normal driving conditions, the distance driven, and the voltage on the ultracapacitors. The addition of these features to the charging system will not only make it more robust than the old system, but will make hardware problems easier to debug and the system more user- and researcher-friendly.

3 System Description and Block Diagram

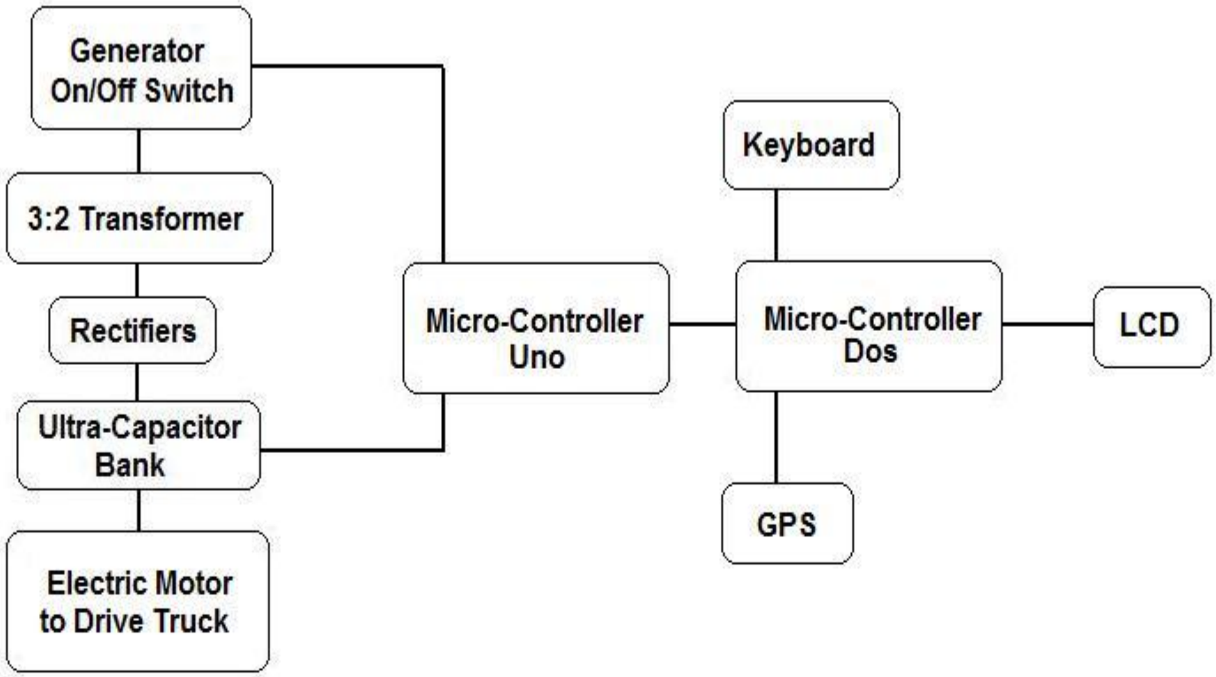

Figure 1. Block Diagram of System

On the left side of the diagram, the block Micro-Controller Uno is shown. This microcontroller is connected to the ultracapacitor bank through a voltage sensor. The sensor will determine the voltage across the capacitor bank and transmit this information to the microcontroller. With this information at hand, the microcontroller will know whether or not the ultracapacitors need to be charged. If they need to be charged, the microcontroller will have to turn on the generator to do so. In order to turn on the generator, the microcontroller will send a signal to a relay which will activate the electric starter of the generator. Also, the microcontroller will have to send a signal to open the fuel valve. Once the generator has turned on and started charging the ultracapacitors, the microcontroller will have to monitor the voltage level on the ultracapacitor bank to know when the maximum voltage has been reached. At this point, the microcontroller will have to send a signal to close the fuel valve and shut off the generator.

Other blocks on the left side of the diagram show the connections between the generator, the transformer, the rectifiers, the ultracapacitor bank, and the electric motor to drive the truck. These components are already in place and will not be amended by us.

On the right side of the diagram, the block Micro-Controller Dos is shown. This block deals with the acquisition of GPS data and the user interface section of the design. The GPS will be able to read values of velocity, latitude, longitude, and altitude of the vehicle. This information can be sent to the microcontroller in order to make calculations such as the prediction of energy needs. Another block seen is the LCD. This block will be used to display to the user the velocity of the vehicle, distance traveled, and miles remaining, along with other information that we may see as being useful to the user.

Another noticeable interface on the block diagram is the connection between the two microcontrollers. These micrcontrollers will need to interface with one another in order to share data about prediction of energy needs in order to control the turning on and off of the engine. The connection between the microcontrollers will also be needed because the voltage sensor on the ultracapacitors will output voltage levels needs to the LCD.

4 System Requirements

4.1 Overall System:

Overall System Requirements	
Purpose	Regulate power distribution to the electric motor of the vehicle by maintaining proper energy levels on the ultracapacitor bank using the electric generator
Generator	Supply sufficient power to ultracapacitor bank using a direct current power supply
Ultracapacitor Bank	Must be able to supply continuous power to the electric motor
Driving Data Analysis	Must be able to analyze and adapt system to current driving conditions
User Interface	Must be able to display current driving condition information such as mile per gallon and distance traveled

4.2 Subsystem and Interface Requirements:

Subsystem Requirements	
Power Control System	
Purpose	Must regulate energy stored in ultracapacitor bank by controlling an electric generator
Generator	Must be able to start and stop diesel generator Must be able to monitor the diesel engine temperature and activate glow plugs when necessary

Ultracapacitor Bank	Must be able to monitor voltage on the ultracapacitor bank Must be able to prevent undercharging of the capacitor bank as well as prevent low charge on the banks
Sensors	Must be able to monitor various sensors such as current sensors, temperature sensors, and voltage sensors
Data Processor	
Purpose	Must be able to take user input and GPS data to determine voltage ranges used by the power control system
GPS	Must be able to read data from onboard GPS and record
Power	Must be able to draw power from the on board starter battery with the generator
Communication	Must be able to communicate with the power distribution controller
User Input	Must be able to receive data from a user input device for options
Display	Must be able to present information about the system on an easy to read display

4.3 Future Enhancement Requirements

Regenerative breaking will be included in the project as long as time and resources allow for it. An existing technology in hybrid electric vehicles that contains capacitors, regenerative breaking involves recharging the capacitors using the energy from friction that occurs during braking. Implementing regenerative braking into the project would result in the problem of overcharging. If the ultracapacitors are at or near their upper voltage limit of 80 Volts, then they should not be charged any further by regenerative braking. The microcontroller would have to interface either with a sensor that could determine if the brakes are being applied, or with a GPS to tell the system that the car is slowing down. If the microcontroller reads that the car is braking and the ultracapacitors are at their maximum capacity, the microcontroller would stop the regenerative braking system from charging the ultracapacitors any further.

5 High Level Design Decisions

5.1 Power Control System

5.1.1. *Generator*

A diesel generator rated at 7 kVA is already in place in the bed of the hybrid electric truck. A 3 gallon tank is on the generator. In order to start this generator, the microcontroller (PIC18F6722) will have to interface with multiple components in the system. A 12 volt battery is connected to the generator to supply power to parts such as the glow plug, the electric starter, and the fuel valve.

5.1.2 *Transformer and Rectifier*

The diesel engine drives a generator that produces a 120 V alternating current. This output is then connected to a 3:2 autotransformer to take the voltage from 120 to 80 volts. After the signal has been transformed, it is fed in parallel to 3 bridge rectifiers that supply an 80 volt direct current to the bank of ultracapacitors. All of the power requirements have been met during previous work and should not be of concern to us.

5.1.3. *Ultracapacitor Bank*

A bank of 34 ultracapacitors rated at 2.7 V each are located in a box in the bed of the truck. They are wired in series and have diode circuitry to dissipate current at high voltages. Each ultracapacitor has an extremely low impedance and when fully charged will have a tremendous current going across them, so they have to potential to be very dangerous if overcharged. With 34 ultra-capacitors, the bank can theoretically hold a 91.8 V charge. To power the electric motor of the car, the ultracapacitor bank should have a voltage above 60 volts. On the other end of the spectrum, the ultracapacitors should not exceed an upper range of 80 volts so as to not break the capacitors by overcharging.

5.2 Data Processing

5.2.1. *Microcontroller*

A microcontroller (Microchip PIC18F6722) will be powered by the 12 V signal from the battery on the diesel generator. The voltage regulator will provide an operating voltage of 3.3 V for the microcontroller board. Our familiarity with this device from the task assignments thus far will be helpful as it serves as the main intelligence hub for inputs and outputs in our system.

5.2.2. *Glow Plug and Temperature Sensor*

The diesel generator may only be started if the cylinder-head is heated to a high enough temperature. During the winter, when most of this project will be carried out, the cylinder-head will be too cold to start up right away. A temperature sensor (Honeywell/Microswitch 6655-90980004) will be used to gauge the temperature of the cylinder-head, and will be powered by the 3.3 V signal from the microcontroller. This is a thermistor based device that will be able to tell us if the temperature is too low.

If the temperature is too low, the microcontroller will be informed of this scenario by the temperature sensor, at which point the glow plug will have to be activated to warm the cylinder-head. The glow plug is a device already on the diesel generator. In order for the microcontroller to activate this glow plug, a 3.3 V signal will be sent to a solid state relay (OMRON LY1-0 DC12) that will make a connection to a 12 V battery to power the glow plug. When the temperature sensor tells the microcontroller that it is at an acceptable temperature to start the generator, the relay to the glow plug will be sent a 0 V signal that disconnects the short between the battery and the glow plug, effectively turning the glow plug off.

5.2.3. *Current Sensor for Starter Motor*

To turn on the starter motor the microcontroller will have to send a signal to a relay (OMRON LY1-0 DC12) interfaced between the battery and starter motor. A 3.3 V signal from the microcontroller will activate the relay and allow the open circuit of the relay between the starter and 12 V battery to close to a short. The starter motor will draw greater than 10 amps of current when this happens and it is trying to start the engine. Likewise, the microcontroller will have to know when the engine is on and the electric starter motor can be shut off. The microcontroller will know this has happened because the load on the starter is significantly decreased now that it no longer has to crank the engine. Because the load on the starter motor has decreased so has the current that the starter is drawing from the battery. The current sensor attached to the line between the battery and starter motor will sense that the current has dropped below a threshold. Then a 0 V signal from the microcontroller will turn off the starter by switching the relay to an open circuit between the battery and starter. The current sensor will be a Honeywell/Microswitch CSLA2CD, rated at 72 A and a supply voltage between 6-12 V.

5.2.4. *Voltage Sensor for Ultracapacitors*

The voltage sensor for the ultracapacitor bank is attached at the rectifier end of the charging circuitry, where the voltage will be highest. The voltage will interface with the microcontroller to let it know the values of the ultracapacitor stack at all points in time. This will allow the microcontroller to decide when to turn on and off the generator in order to charge the ultracapacitors.

5.2.5 *Global Positioning System (GPS)*

Using a GPS module will allow the data processing system to retrieve real time vehicle data, such as vehicle speed location. Storing real time data is useful for predicting future energy needs.

5.2.6 *Liquid Crystal Display (LCD) and Keyboard*

User interface is desired for this project in order to display important and useful information. An LCD display (Matrix Orbital LK162-12-GW) will interface with the microcontroller and give the user on screen values for velocity, distance traveled, the voltage across the capacitors, and the time necessary to wait before the engine is warm enough to start. These values will be either computed or read from other components in the system such as the temperature sensor on the cylinder-head or the GPS. A keyboard will allow a user to configure certain system parameters in real time.

6 Open Questions

While the overall goal of the hybrid system is to regulate the power distribution of the vehicle, other systems can be incorporated. A 'smart' system can be added to the control system by incorporating a data processor. The data processor will read data from the vehicle itself and from user input. Using various algorithms, the processor can analyze the data and determine future energy needs. The data can be stored and used again if the vehicle follows a similar route.

Overall, prototyping of the system will not require major development work. Preexisting microcontroller boards and parts can be used to develop a working control system for the power distribution.

7 Major Component Costs

Part	Part Number	Price
Current Sensors	CSLA2CD	$19.39
Relays	LY1-0-DC12	$5.73
Temperature Sensor	6655-90980004	$6.50
GPS Module	ISM300F2-C4	$29.95
GPS Active Patch Antenna	ACTPAT254-01-IP	$9.15
Microcontroller	PIC18F6722	$12.54
LCD Display	LK162-12-GW	$49.95

8 Conclusions

The hybrid electric truck already has a few very important system components established, but we have a great opportunity to elaborate on these systems and improve their functionality. The system will become more autonomous through the implementation of a control system with algorithms to determine when to turn the generator on and off based on the voltage level of the ultracapacitors and the current driving conditions. It will also be more user-friendly in providing the end user with real-time data regarding the vehicle's energy usage.

The project will provide several important improvements to Dr. Bauer's hybrid electric truck and will bring large benefits to all participants. Dr. Bauer will gain a significantly more robust and reliable vehicle for his research. The user-interface additions will make the hybrid system much more user-friendly and will allow Dr. Bauer to expand the breadth of his research on the vehicle thanks to the data acquisition and storage systems.

But this vehicle also represents a real opportunity for us, the designers and constructors. It introduces us to aspects of system design, hardware-to-hardware interfacing, hardware-to-software interfacing, as well as pure software-to-software interfacing. We believe that this project has an ideal combination of hardware and software components that will allow us to gain exposure and experience in several different areas. We also benefit from the footwork and lessons of our fellow electrical engineers who worked on this system the year before. The work that has already been performed on this system puts us in the enviable position of having several necessary system components worked out while leaving enough challenges left over to provide a worthwhile project.