A Novel Electric Vehicle Drive System

Christopher C. Arnold and Kevin T. Tran
University of Arkansas - Fort Smith
5210 Grand Avenue, Fort Smith, AR 72913-3649

Abstract

The conversion of vehicles from petroleum based fuels to Battery Electric Vehicles (BEVs) has been slow due to limited driving range and lengthy recharging times. A novel powertrain to increase utility of BEVs is being developed at the University of Arkansas – Fort Smith. The key component of this powertrain is the use of a 5-speed transmission matched with a specialized electric motor. This powertrain can be adjusted to match needed road performance and optimized for energy efficiency in passenger vehicles and light weight delivery vehicles. This project continues to build a bridge between local business, industry, and the University of Arkansas – Fort Smith in motor development and specialized parts needed in this powertrain. As this technology matures, it is foreseeable that new businesses and industries could result.

Battery Electric Vehicle Specifications

The second generation BEV uses a 335 V system is powered by GBS LiFeMnPO4 batteries; these 60 Ah batteries are rated at 3 C to allow a constant output of 180 A for one hour and 600 A for 10 seconds. The prismatic battery set weights 550 pounds with an energy density of 100 Wh/kg. This second generation vehicle incorporates a 2.2 L, 5-speed GM transmission to better match driving conditions. Figures 1 through 4 provide data for motor shaft speed and torque which is coupled in the final design to a 5-speed transmission. Figure 1 shows the motor speed produced as the dynamometer increases the load torque until motor stall or pullout. Peak torques is achieved between 1200 to 1780 RPM. Figure 2 indicates the peak 146 A current demand is at 1780 RPM producing a maximum torque of 150 Nm. The produced torques shown in Figure 2 were not limited by drive current as the motor drive was oversized and could sustain 150 A continuously. The set of curves highlighted in Figure 3 indicate the predicted motor torques needed for first through fifth gear applied to the 5-speed transmission to accelerate a 1900 kg vehicle from 0 to 60 MPH in 10 seconds. The yellow zone in this Figure 3 indicates the vehicle can be accelerated using third or fourth gear of the transmission while staying within the torque limits of the traction motor. Figure 4 indicates motor torque needed to maintain a constant speed traveling on level ground; this torque demand includes rolling and air resistance. With the 5-speed transmission in fifth gear, the needed motor torque is 93 Nm at 1660 RPM which is equal to a vehicle speed of 60 MPH. This falls within the limits of the motor/drive capabilities. Figure 4 also indicates a maximum vehicle speed of 80 MPH is obtained with the transmission in fifth gear. Figure 5 is a photograph of the traction motor used in this project. This motor is totally enclosed to protect against dust and water damage. The motor also has an aluminum frame to quickly dissipate heat and reduce weight.

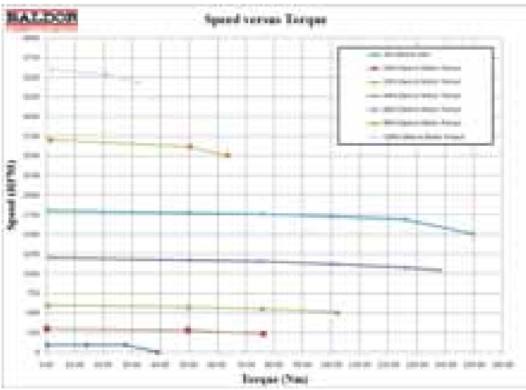

Figure 1: Torque produced by customized traction motor used in second generation Electric Vehicle (EV). This motor produces maximum torque between 1200 to 1780 RPM[1].

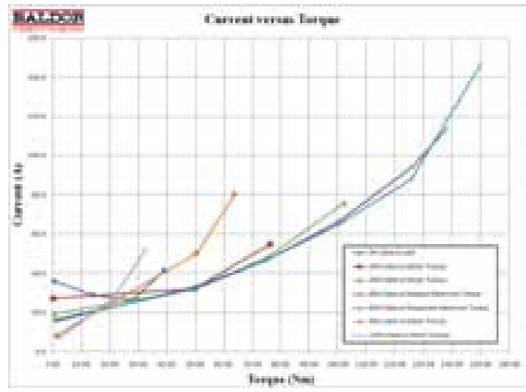

Figure 2: Motor current needed to produce demanded torque in this electric vehicle application. Current demands fall within capabilities of Li batteries and motor

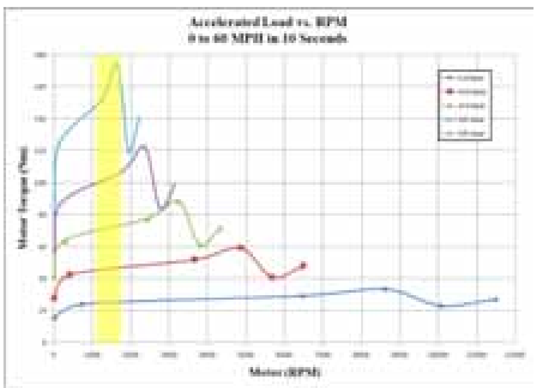

Figure 3: Predicted torque needed to accelerate a 1900 kg EVfrom 0 to 60 MPH in 10 seconds using a GM 2.2 L, 5-speed transmission. Speeds between 1200 to 1778 RPM are highlighted in yellow where the traction motor produces the most torque. This traction motor is rated for a maximum of 5000 RPM.

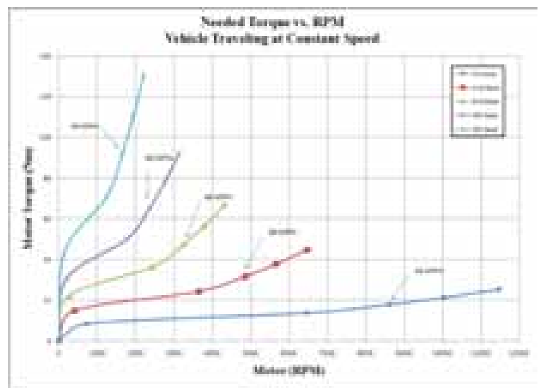

Figure 4: This figure shows the predicted torques needed to maintain EV speed. The EV is 1900 kg and uses the transmission described in Figure 3. Rolling and air resistance was taken into account with these values.

Figure 5: Photographs showing customized motor designed for second generation BEV and 5-speed manual transmission.

Conclusions

Testing has indicated that the motor/drive/LI battery will provide proper torques and current limits to operate the G5 under normal driving conditions. The next steps to be taken are mounting the motor to 5-speed transmission in the vehicle and testing the actual performance. If driving tests are favorable, work can begin on improving vehicle efficiency and designing a new motor drive to better match automotive requirements.

References

1. http://www.baldor.com/products/ac_motors.asp

Bibliographical information

Christopher C. Arnold and Kevin T. Tran will be receiving a BS in Electrical Engineering spring 2013. Both students will be pursuing advanced degrees in engineering. Christopher and Kevin have worked on the Electric Vehicle Project (EVP) for over one year. Emails: carnol02@g.uafortsmith.edu and ktran00@g.uafortsmith.edu.

A Novel Electric Vehicle Drive System

C.C. Arnold, K.T. Tran, and K.R. Lewelling, PhD, PE
Department of Engineering
University of Arkansas – Fort Smith
5210 N. Grand Avenue
Fort Smith, AR 72913-3649

Abstract

The conversion of vehicles from petroleum based fuels to Battery Electric Vehicles (BEVs) has been slow due to limited driving range and lengthy recharging times. A novel powertrain to increase utility of BEVs is being developed at the University of Arkansas – Fort Smith. The key component of this powertrain is the use of a 5-speed transmission matched with a specialized electric motor. This powertrain can be adjusted to match needed road performance and optimized for energy efficiency in passenger vehicles and light weight delivery vehicles. This project continues to build a bridge between local business, industry, and the University of Arkansas – Fort Smith in motor development and specialized parts needed in this powertrain. As this technology matures, it is foreseeable that new businesses and industries could result.

Support

The Electric Vehicle Project (EVP) is being supported by ABB Baldor, Rheem/Ruud, Arkansas Space Grant Consortium (ASGC), Arkansas Student Undergraduate Research Fellowship (SURF), and the University of Arkansas - Fort Smith. This project has involved over 55 undergraduate students with contributions from 5 local companies. The authors would like to gratefully thank each organizations that contributed to this work.

Battery Electric Vehicle Specifications

The second generation BEV uses a 335 V system powered by GBS LiFeMnPO4 batteries shown in Figure 8a; these 60 Ah batteries are rated at 3 C to allow a constant output of 180 A for one hour and 600 A for 10 seconds. The prismatic battery set weights 550 pounds with an energy density of 100 Wh/kg.

This vehicle incorporates a 2.2 L, 5-speed GM transmission to better match driving conditions; this transmission is shown in Figure 7b. Figures 1 through 4 provide data for motor shaft speed and torque which is coupled in the final design to a 5-speed transmission. Figure 1 shows the motor speed produced as the dynamometer increases the load torque until motor stall or pullout. Peak torques are achieved between 1200 to 1780 RPM. Figure 2 indicates the peak 146 A current demand is at 1780 RPM producing a maximum torque of 150 Nm. The produced torques shown in Figure 2 were not limited by drive current as the motor drive was oversized and could sustain 150 A continuously. The set of curves highlighted in Figure 3 indicate the predicted motor torques needed for first through fifth gear applied to the 5-speed transmission to accelerate a 1900 kg vehicle from 0 to 60 MPH in 10 seconds. The yellow zone in this Figure 3 indicates the vehicle can be accelerated using third or fourth gear of the transmission while staying within the torque limits of the traction motor. Figure 4 indicates motor torque needed to maintain a constant speed traveling on level ground; this torque demand includes rolling and air resistance. With the 5-speed transmission in fifth gear, the needed motor torque is 93 Nm at 1660 RPM which is equal to a vehicle speed of 60 MPH. This falls within the limits of the motor/drive capabilities. Figure 4 also indicates a maximum vehicle speed of 80 MPH is obtained with the transmission in fifth gear. Figure 7a is a photograph of the traction motor used in this project. This motor is totally enclosed to protect against dust and water damage. The motor also has an aluminum frame to quickly dissipate heat and reduce weight.

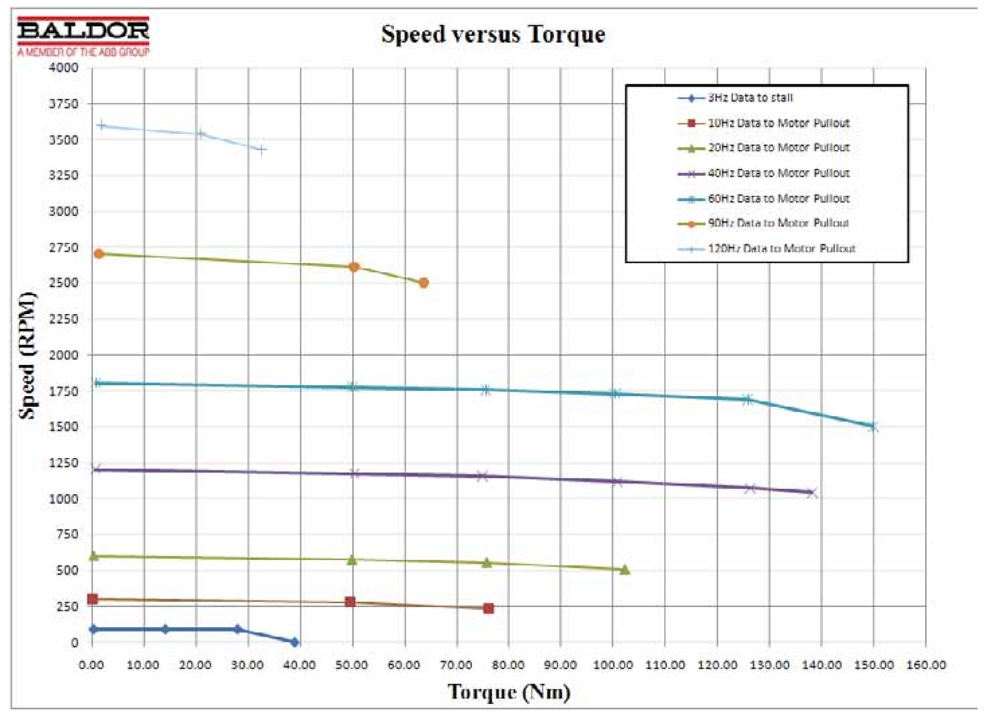

Figure 1: Torque produced by customized traction motor used in second generation Electric Vehicle (EV). This motor produces maximum torque between 1200 to 1780 RPM.

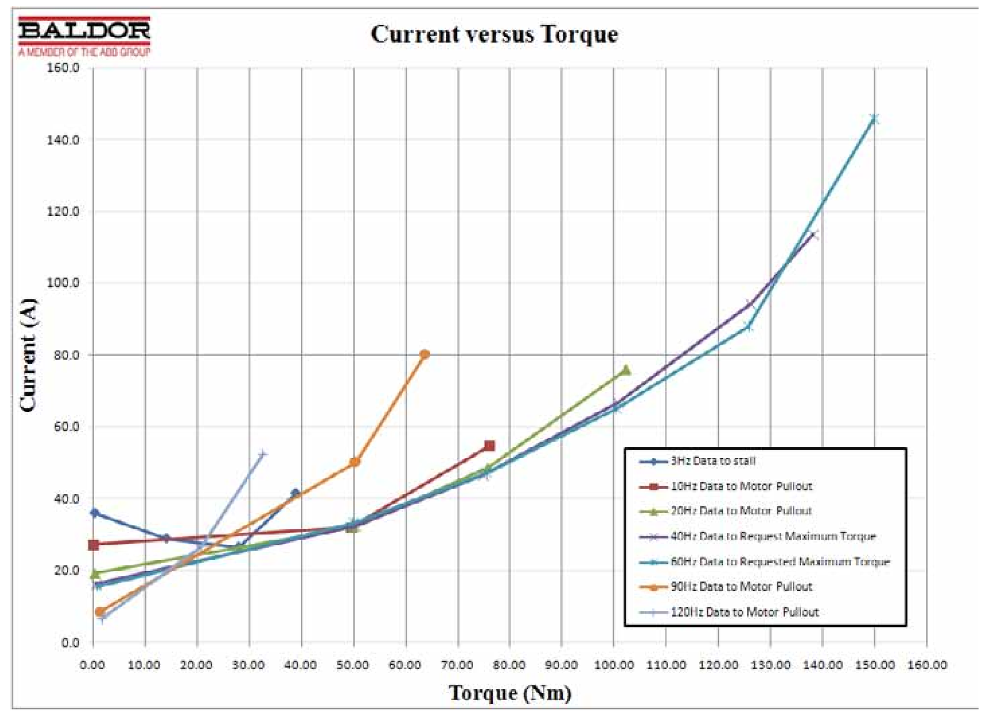

Figure 2: Motor current needed to produce demanded torque in this electric vehicle application. Current demands fall within capabilities of Li batteries and motor controller.

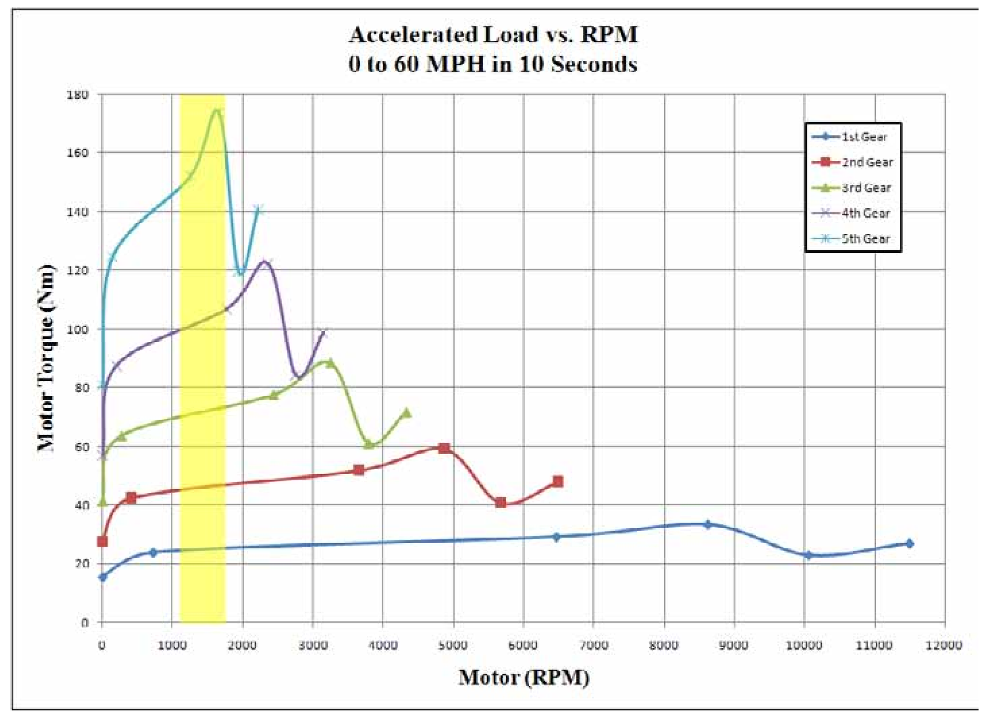

Figure 3: Predicted torque needed to accelerate a 1900 kg EV from 0 to 60 MPH in 10 seconds using a GM 2.2 L, 5-speed transmission. Speeds between 1200 to 1778 RPM are highlighted in yellow where the traction motor produces the most torque. This traction motor is rated for a maximum of 5000 RPM.

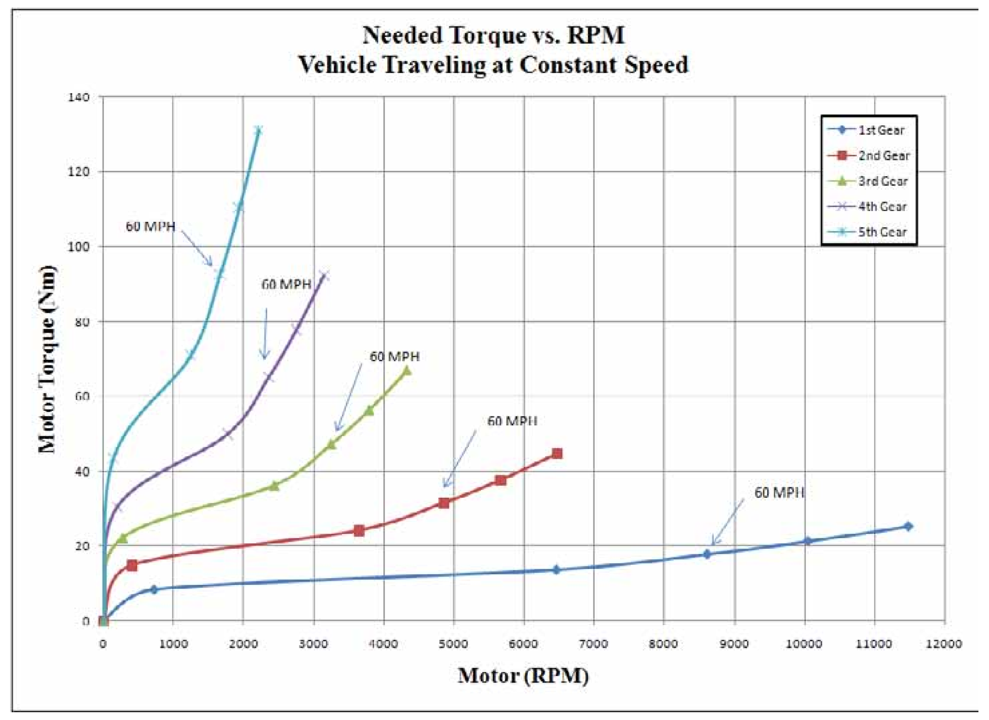

Figure 4: This figure shows the predicted torques needed to maintain EV speed. The EV is 1900 kg and uses the transmission described in Figure 3. Rolling and air resistance was taken into account with these values.

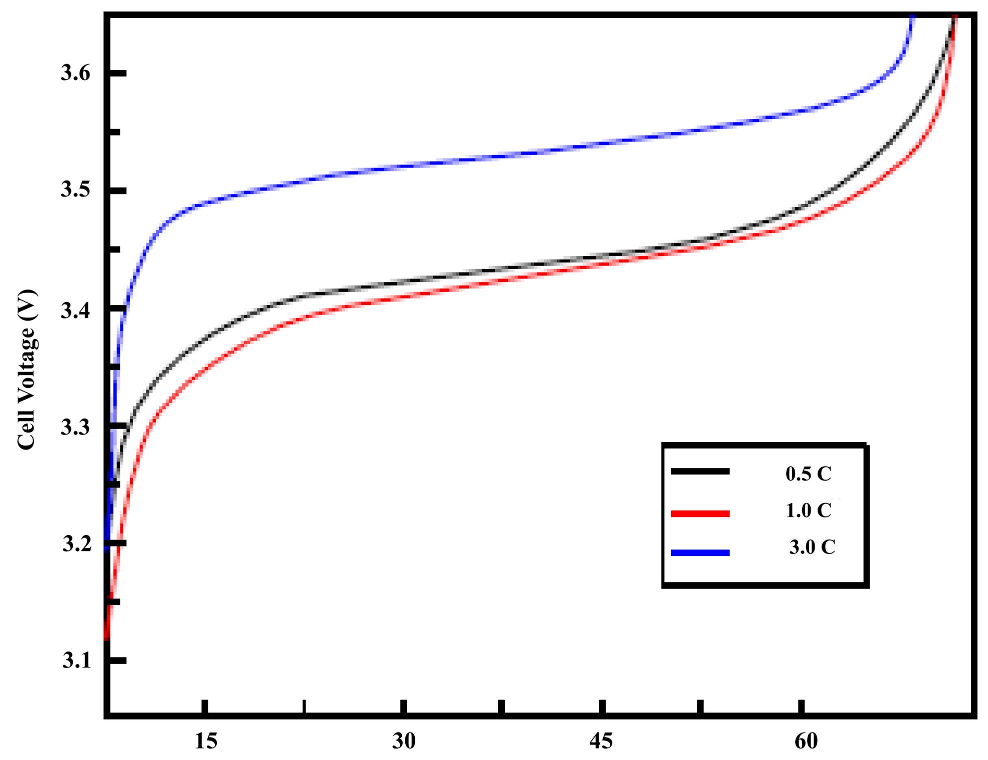

Figure 5: These curves show cell voltage for different charge rates, 0.5 C, 1 C, and 3 C. Nominal cell voltage is 3.2 V. Data provided by Elite Power Solutions.

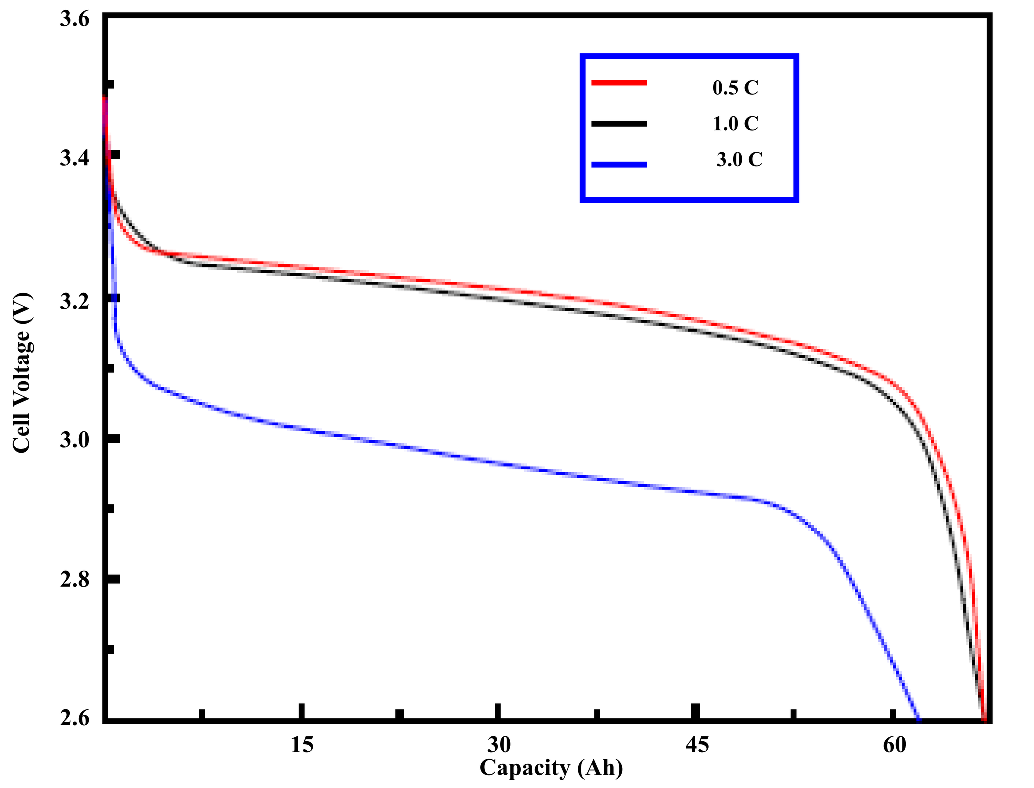

Figure 6: These curves show cell voltage for different discharge rates, 0.5 C, 1 C, and 3 C. Nominal cell voltage is 3.2 V. Data provided by Elite Power Solutions.

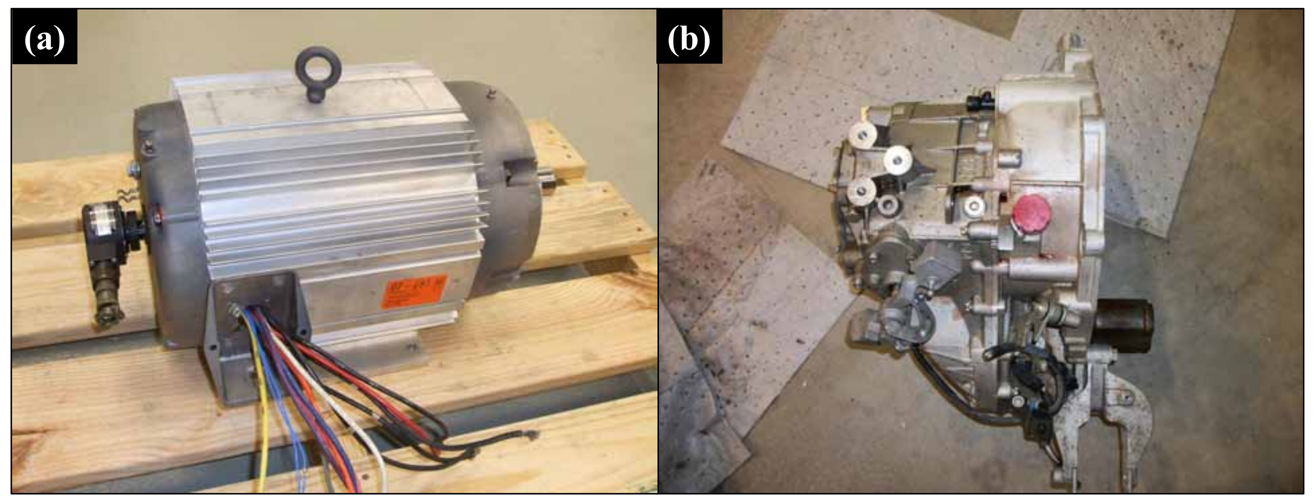

Figure 7: Photographs showing customized motor (a) designed for second generation BEV and 5-speed manual transmission (b) used in the new design.

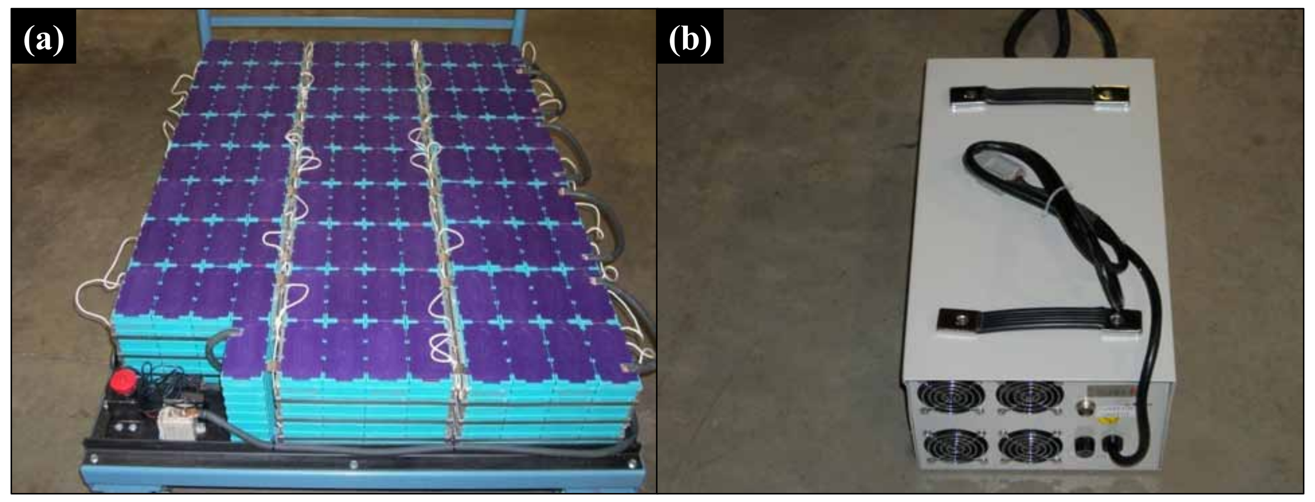

Figure 8: Photograph (a) shows the LiFeMnPO4 battery pack used in the second generation EV and (b) custom 105 cell battery charger on the right. The batteries can be recharged using a standard 120/240 V electrical outlet. This battery bank will eventually be placed in the trunk of the second generation EV.

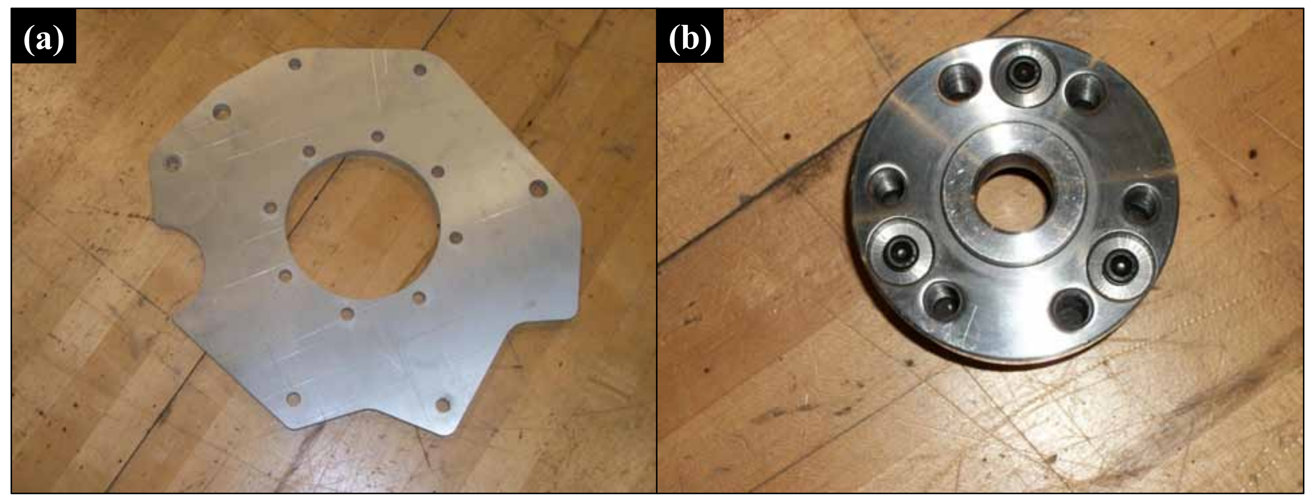

Figure 9: Picture (a) shows the mounting plate used to secure the electric motor to the 5-speed transmission. The mounting plate was fabricated using a water jet cutter by the Rheem corporation. Picture (b) shows the custom flywheel hub designed to secure the flywheel to the electric motor shaft.

Educational Outreach

The Electric Vehicle Project (EVP) has involved over 55 UAFS students since its inception. The electric vehicle has been taken to three high schools and five middle/junior high schools for visits in the past three years. These visits included a presentation over energy generation and conservation with hands-on activities for the students. At each presentation, current electrical engineering students describe their experiences associated with university studies and work on the EVP. The aim of this outreach effort is to encourage young students to pursue STEM careers by letting them experience firsthand what it is like to design and build an electric vehicle.

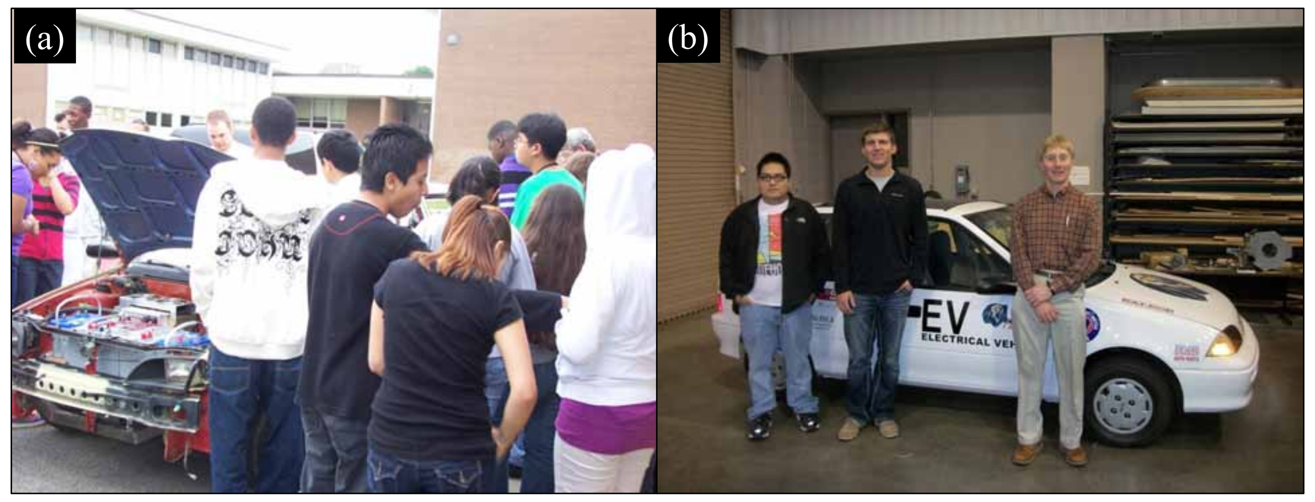

Figure 10: (a) Shows students at Kimmons Junior High School looking at the EV. This presentation discussed EVs and energy conservation. Figure 8(b) shows students Chris Arnold, Kevin Tran, and Kevin Lewelling (PI) with the first generation EV in the background.