Converting a Porsche 914 to an Electric Vehicle

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Abstract

Due to rising fuel costs and increased environmental concerns, electric vehicles (EVs) are becoming more popular. Efficiency is the key to building any worthwhile vehicle, but it is especially important when fabricating a car with limited range like an EV. Our progress in converting a 1973 Porsche 914 from conventional gasoline power to an all electric drive and the decision making process involved in its construction are described.

Our goal is to create a moving test bed that is fully upgradeable as well as to outfit the fastest, most efficient electric car possible using lead acid batteries. It will serve as a rolling classroom, not only for those building the initial car but also for future students who will eventually modify and advance its design.

The main calculations involved were deciding the tradeoffs between components as they affect overall efficiency. The choices included which controller to use, how to power the accessory system, how to route the power cables and which batteries to install, among several other things.

Introduction

The world is quickly moving to a place where alternative fuels and ways to power vehicles are becoming increasingly important to the environment and economy. Recently, electric vehicles and hybrid cars have begun to rise to this challenge. In order to better understand how far electric cars will eventually take us, we endeavor in these experiments to understand the principles behind these vehicles and their respective systems.

In order to fully accomplish these goals, however, several iterations of this project will be necessary. It is our intention, therefore, to begin by creating a solid prototype that focuses on the bare essentials of an EV, in an effort to create a research platform for future students. Once the first version is completed, more complicated systems, such as

regenerative breaking and implementation of solar panels, can be researched and added. This report will document the evolution of the first model.

The research was done with all battery technologies in mind; however, the experiments performed and planned have been created to analyze EVs using lead-acid batteries. This distinction is due to a lack of availability and the high costs involved with other kinds of batteries as well as the reliability of lead-acid in this setting.

A 1973 Porsche 914 was acquired to be the vessel of our experiments. During our research a previously converted Jeep Grand Cherokee became available and was donated in order to be used as not only a source of components but a model of our end goal. It allowed us to see how the theory behind all the elements being studied could be used in practice. The Jeep was also 4-wheel drive and powered by roughly 144 volts, meaning its motor would be an excellent selection for our vehicle.

The "tear down" of the Jeep and concurrent theoretical research allowed us to gain a complete grasp of the task at hand before the Porsche was ready for installation. During this time, the Porsche was stripped of all its components and chemically dipped to eliminate any rust; primer was then applied. Once back, the body was shored up with added reinforcements where it had rusted through. The car's basic components were added next and the construction process is ongoing.

Phase 1: Dismantling a Completed EV

The first part of this project focused on the Jeep Grand Cherokee that was procured in the beginning stages of research.

Figure 1 – The Jeep EV before major deconstruction work began

Procedure

The Jeep was disassembled in stages moving from front to back while leaving the drive train for the end. This approach resulted in an extraction of mostly secondary system components first. The dissection began in what was the engine compartment by taking off the hood. The controller, battery box, DC to DC converter, circuit breaker, throttle and accessory battery were then removed along with their accompanying wiring. The dismantling continued in the cab where the main gauges were salvaged and the safety kill switch mechanism was examined. The trunk and its associated charging unit was the last area examined. A second battery box complete with its own fan was also recovered.

Analysis

Much of the technology inside the Jeep was very esoteric at first. Heating elements were found inside the battery boxes. An auxiliary battery was used to power the Jeep's accessories but a DC to DC converter was used in lieu of an alternator. Computer fans where placed all over the engine compartment and battery boxes. Two circuit breakers where in use in conjunction with semiconductor fuses and the master kill switch was a simple bolt of wire ran from one of these breakers through the dash and attached to a pull knob. The gauges in the dash ranged from a Wattmeter to an Ammeter to a Voltmeter to a temperature gauge.

Several resources were consulted and tested to arrive at the answers to the questions all of these discoveries prompted. The heating elements inside the battery boxes are there to maintain a temperature in colder weather because lead-acid batteries perform better at around 78 ^{o}F due to the chemical reactions involved, all of which are influenced by temperature.[1] The absence of an alternator is due to the intermittent restrictions of alternators as they pertain to DC motors in EVs. An alternator has to be fed by a rotating shaft in order to create a charging voltage, but an EV's DC motor isn't always running. Coasting is the key to driving any EV because it saves power in the main battery packs, but the downside to this is that it limits how long the drive shaft will be rotating prohibiting a constant mechanical rotating input to an alternator. The fans placed around the EV are not only for cooling important circuit elements such as the controller but also to dissipate large buildups of hydrogen gas which is given off by chemical reactions involved with charging lead-acid batteries.[1] Each circuit breaker isolates one set of batteries (one in the engine compartment and one in the trunk for this case) and the semiconductor fuse is to protect the controller because a standard fuse and circuit breaker is not fast enough to protect the controller in the event of a fault.[2] The mechanical kill switch is used instead of an elegant electrical switching mechanism because of the safety related nature of the component. There must be no doubt that this component will accomplish its function every time regardless of outside circumstances. The Wattmeter and Ammeter are the most influential gauges in any EV because they declare how much power is leaving the batteries and at what rate; they are the most accurate way to decipher how much energy the battery bank. Temperature gauges are also very important in helping to alert the driver of problem areas with respect to cooling or, at worst case, a limited fault warning. Voltmeters in EVs are useful but are limited in that they do not give an accurate reading if the battery pack has been in use for an extended period of time. They do, however, give useful readings corresponding to the baseline voltage of the battery pack before driving.[1]

Phase 2: Porsche Construction

The second part of this research project required a couple shifts in concentration; the first being a move from reverse engineering to design and then another from design to assembly.

Figure 2 – The Porsche after being chemically stripped and primered

Design Decisions

Several elements of the Jeep have been integrated into the Porsche's design; however, there are several performance changes in addition to what is involved with changing vehicle types. The key change involves the controller; the Porsche will be equipped with the Zilla Z1K-LV controller and its "hairball" interface. This the most advanced DC motor controller designed for EVs on the market today. Its system settings are fully programmable with use of a PC or Mac in order to set the controller for a car with better endurance or max performance. Its voltage and current rating are 72-156V and 1000A, respectively.[2] All of the cables for the propulsion system, including the batteries, motor and controller, are stranded 4/0 welding cable. The cable was selected to handle the highest currents possible from the controller with the least resistance; they are stranded because they are easier to bend and work with in the conduits we will be using. They were run inside a compartment that stretches from rear to front along the passenger side door, which is on the opposite side of the car from the control wiring to prevent interference.[3] This layout could of course be flipped, but it is preferable to limit driver exposure to these high voltages and currents. These compartments will be enclosed by bolt-on pieces that can be removed easily for maintenance and upgrading. These long cable runs are limited to the ones between the battery pack to limit I^2R losses in the

conductors. The motor itself will be the same series DC motor pulled from the Jeep. Safety interlocks have been designed and will be implemented to prevent unloading of the motor while it is running to prevent a runaway condition. An example of these interlocks is that when the brake or clutch is pushed, the power to the motor will be interrupted. Along with these motor safeguards additional safety interlocks will be employed that will prevent flow of electricity to the propulsion system when charging, announce the vehicle is on and disallow exit when the vehicle is running among other things. A DC to DC converter used to charge a standalone battery was the design chosen to power the accessories, emulating the Jeep's method. While the alternator option wasn't pursued for reasons stated above, a single standalone accessory battery was neglected due to the power restrictions of a 12V battery. The accessories would function at a lower capacity with a single 12V power source, but they would give out more quickly. That configuration would also make upgrading to water cooling for the controller, if necessary later, more difficult.[4] Another departure from the Jeep's design is the charging unit itself, since the Porsche was designed for performance and will only be used near TCU's campus, no onboard charging system will be installed. Instead, a base charger will be installed in TCU's Engineering building.

Building Progress

The installation process is a long one, due in part to the lead time on the Zilla controller. The motor and transmission have been installed as well as the throttle cable and potentiometer. The battery boxes have been built and the cable layout is finished. The main automotive components have been reinserted and the car is at a bare-bones state for electrical components of the propulsion system to be installed. Everything necessary has been ordered and some of it salvaged from the Jeep but until the controller arrives, the wiring harness and the accessory wiring cannot be completed. During this period, however, all the electrical layout drawings are being finalized.

Summary and Conclusions

EVs are the cleanest form of transportation in the world today, helping deter the massive environmental toll travel has on the planet, and they cost less to maintain and operate than conventional gasoline powered vehicles.[5,6] EVs also afford a unique research opportunity into varying fields of engineering.

Even this project is a compilation of many different studies into the fields of motors, energy storage, controls and electrical system design. Every component has a unique affect on the efficiency of the EV. All the design decisions for this car have been made with velocity in mind as well as maximizing the range for these performance based decisions. Much of the research into these processes came from literature study but the greatest portion of knowledge was garnered through the reverse-engineering of the Jeep.

After performing over a year of research into this area, one can discover a multitude of ways to build and improve the performance of an EV. It is extremely important, however, to define a purpose early in the project that sets the tone for the components and chassis involved. There is also a great opportunity to incorporate several different fields of research into this type of a project. New charging opportunities include solar panels, regenerative breaking and MEMS energy storage systems, but the vehicle's

research opportunities even span to areas such as photonics as they relate to data communication, whether that be between systems using optocouples or to the driver via head up displays. Our electric car can and will serve as a great learning tool for several fields of engineering at TCU going forward.

Acknowledgements

The author would like to thank Jon Eidson for donating the previously converted Jeep Grand Cherokee as well as the other members of TCU's EV team for their assistance and dedication.

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