Unit L: Controller & Control Enclosure Subassembly

Overview

The controller controls the amount of energy that flows from the battery pack to the motor. Controlling this voltage controls the speed of the motor. It is like the carburetor or fuel injector of the EV, except that the fuel it is "injecting" is electricity. The Control Enclosure contains multiple components to manage the controller, its safety and other EV accessories.

Motor Controller

Figure 8

Solid state controllers are actually quite advanced. They use a high frequency that pulses and allows electricity to flow at different rates, giving the system infinitely variable drive. Forklifts, carts, material handling, tow tractors and other industrial vehicles have used them for years. Figure 8.

The controller we will be using for our 9" motor is made specifically to provide smooth, silent efficient speed and torque for our vehicle. It is programmed to be used in a commuter vehicle application, with built in safety features like thermal protection to prevent overheating, under-voltage cutout to prevent low battery rundown, and fault circuitry to prevent runaway.

We are working with high direct current voltage. Some safety precautions should be taken while handling or using the controller. These include:

- Prevent runaways –always raise drive wheels from the ground when performing test or maintenance procedures with the vehicle.
- Arcing current –there is high power in the EV's battery pack, arcs can occur if the pack is short circuited. Always wear safety glasses and use insulated tools.
- Battery considerations –charging and discharging batteries produces hydrogen gas, which can build up in the battery area. ALWAYS FOLLOW BATTTERY MANUFACTURER SAFETY PRECAUTIONS AND RECOMMENDATIONS.

The Controller is a true "black box" with no adjustments necessary for installation or tuning. Settings are determined and performed at the factory. The controller can be mounted in any position that is clean and dry. We will mount the controller to a safety heat sink in the motor compartment. This procedure is described in the assembly sequence.

Heat Sink

Figure 9

The controller is mounted on an aluminum plate in the engine compartment. This plate is called a heat sink because it helps keep the controller cool. The heat sink is bolted into the engine compartment in an easily accessible location. We use a heat sink to dissipate excess heat from operation of the controller because a lot of electricity flows through it. Figure 9.

Our controller is mounted underneath the heat sink to utilize

natural convection to eliminate heat. We use a heat compound to facilitate the flow of heat from the controller to the finned heat sink. We use the enclosed mounting clamps to bolt the controller into place on the heat sink.

You may notice additional fins on the controller; these are also to facilitate cooling. Heat transfer grease is also used between the controller and heat sink to help dissipate heat. The controller has an emergency shut off built into it to limit its output if it reaches a critical temperature threshold.

Potentiometer

The controller throttle input is 0-5k Ω. Our potentiometer is matched to this input requirement. The operator will use the stock gas pedal on the finished vehicle. When the driver steps on the pedal it connects by cable to a lever on the 5K Ohm Potentiometer or 5K Ohm Pot Box. This turns mechanical motion of the gas pedal into an electrical switch for the controller. The foot pressure on the pedal will feel the same to the operator as it did on the ICE. Figure 10.

Figure 10

An additional safety feature in the potbox is a built-in Microswitch which activates the contactors when the accelerator is depressed. The potbox will be mounted to the outside of the control enclosure and attached to the throttle cable as described in the video.

Throttle Microswitch

Vehicles should use a throttle activated micro switch to protect against runaways in the event the forward/reverse switch gets stuck in either direction. Every potbox should have a micro switch feature built in or added to it.

Throttle Return Line

The operator will use the stock gas pedal on the finished vehicle. One important consideration is the return mechanism. The pedal must return to its resting/off position safely and naturally. This also helps the driver feel comfortable using the EV, so it feels just like an ICE car or truck.

Control Box Enclosure

The conversion uses a non-metallic control enclosure to house the components that support the controller. The control box enclosure provides a clean dry environment for these sensitive components. It is designed with a see-through outer casing so the parts can be viewed safely without touching them. These components in the enclosure are described below.

Main Contactors

We will install two large relays that can connect and disconnect the car's battery pack to and from the controller. This relay turns the car "on" when you want to drive it, and the relay can carry hundreds of amps and that can “break” pr interrupt 96 to 300 volts DC without holding an arc. Figure 11.

Figure 11

We use two contactors on the S-10, one for the positive and one for the negative side of the circuit. The primary contactor will be activated during key-on. The secondary contactor will be activated with the potbox. The contactor's positive terminal is clearly marked with a positive (+) designation.

Coil Suppression Diode

A coil suppression diode should be used on the contactor coil. The rapid changing of the controller's internal filter capacitors causes a high inrush current to flow briefly when the contactor closes. To extend contact life, a precharge resistor can help by precharging the capacitors and reducing the inrush current through the contacts. The coil suppression diode on our system is attached directly to the contactor. Figure 12.

Figure 12

KLK High Voltage Fuse & Fuse Holder

This protects the 144volt control circuit. We need to take 144 voltage and feed it to the controller to tell it that the system is charged (turned on) and ready. We also can use the 144 volt circuit for meters that measure the status of the battery pack.

KSI Switch (KSI)

The controller KSI is used to turn the controller on and off. The keyswitch input circuit includes inputs from the keyswitch and from the various interlocks. The KSI is turned on by connecting it to battery B+. Any positive voltage greater than about 8 volts will turn on the controller, but usually the full traction battery voltage is used.

The KSI is usually connected to the ignition switch. This will act as a safety feature by removing power from the motor control system when the key switch is off. Just like any ICE vehicle, the electric vehicle cannot be powered on without the key. Location of the keyswitch positive wiring is described in the video portion of the assembly sequence.

12 Volt Terminal Strips

We will use one terminal strip on each side for positive and negative connections. The negative ground strips provides a good terminating point for negative circuits. The 12 volt key-on voltage attaches to the positive terminal strip, powering it for use with other circuits.

Multi-position Fuse Holder

The blade style fuse holder provides safety for the control circuit, accessory and gauge fuses. Its installation and fuses to be used will be described in the assembly sequence.

Unit L Lesson Plans

Students will

- Have a basic knowledge of the function and location of the electronic MOSFET controller;
- Understand the design and function of supporting components in the controller enclosure; and
- Understand safety features built into controller and subcomponents

Materials

- Unit L text
- ElectricAutoshop PowerPoint video
- ElectricAutoShop DVD
- Appendix H Troubleshooting
- System Component: Controller and related subcomponents

Procedures

1. Review the relationship between the controller, heatsink and potbox. What causes heat to be generated in the controller? What safety features are built into the controller to assist it in managing heat and current? What is the function of the potbox?

2. Now have students lay out the components of the control box enclosure. Name the components are their function. Verbally "connect" them by discussing their assembly locations in the enclosure.

3. Have students consider these questions:

    - ✓ What is the function of the microswitch?
    - ✓ What is a major consideration for the throttle return?
    - ✓ What is the function of the KSI switch?
    - ✓ What are contactors?
    - ✓ What is the function of the coil suppression diode? Where is it located?

4. Have students answer the following questions about the electronic controller.

    - ✓ Besides commuter cars and truck, what are other applications for the electronic controller? (Forklifts, carts, material handling, tow tractors and other industrial vehicles.)
    - ✓ What is the voltage of our control system?
    - ✓ What happens when battery voltage becomes extremely low? Why?
    - ✓ What happens if the driver accidentally starts the EV with his foot on the pedal?

Evaluation

Use the following ten-point metric to evaluate students' work during this lesson.

- **Ten points:** Students grasped the concept of electronic speed control and safety management; mastered definitions of parts in the control system, clearly understood the interaction of controller and system subcomponents, understands the safety feature of EVERY component.
- **Five points:** Students recognized the concept of electronic speed control and safety management; understood most definitions of parts in the control system, understood the interaction of controller and system subcomponents, understands the safety feature of EVERY component.
- **One point:** Students had difficulty recognizing the concept of electronic speed control and safety management; had difficulty with definitions of parts in the control system and system subcomponents, understands the safety feature of EVERY component.

DO NOT ALLOW STUDENTS TO PROCEED UNTIL THEY UNDESTAND THE SAFETY FEATURES OF ALL COMPONENTS IN THE CONTROL SYSTEM.

Extensions

- Have the class discuss the main function of the controller and why it is good or bad that it is designed as a closed black box system.
- Ask students to predict changes or improvements they might see in control systems in the next 10 years.
- As a class, discuss power control for accessories, how they may have an effect on range and performance.

Vocabulary

acceleration rate
Definition: a built in acceleration rate circuit maintains a maximum rate of power increase to the motor. If the throttle is applied full on at start up the acceleration rate setting determines how quickly the controller output increases. The standard setting is such that with full throttle, the controller requires approximately one second to reach full output. This feature enhances smooth starting.
Context: EVs have features in their controllers that control the acceleration rate for smooth starts that help conserve their power and provide comfort to the driver.

current limiting
Definition: Controllers have a built in limiting feature which protects the controller from excess current. Without this feature controllers would be vulnerable to maximum current draw from motors. This feature protects other part of the system too, stress on batteries and motor are eliminated, wear on other components is reduced.
Context: The EV has current limiting built in to its controller to protect against excessive heat and wear.

environmental protection
Definition: controller components are housed in sealed enclosures to provide

environmental protection
Context: Controllers are sealed and protected from outside elements, these enclosures also provide environmental protection by keeping all electronic components contained.

frequency shifting
Definition: frequency shifting helps protect the controller by switching from 15 kHz to 1.5 kHz when the motor is near stall conditions.
Context: Near stall conditions may harm the motor or controller, the controller protects against this by using frequency shifting.

high pedal disable
Definition: the EV is protected from accidental acceleration while being turned on with the pedal depressed by high pedal disable.
Context: high pedal disable is a safety feature built in to the controller and prevents accidental acceleration.

MOSFET
Definition: a fast switching transistor (Metal Oxide Semiconductor Field Effect Transistor).
Context: MOSFET technology allows controllers to perform smoothly and efficiently.

stepless operation
Definition: stepless operation is the effect of smooth acceleration by using electronic switching.
Context: as the EV performs with stepless operation it accelerates without any noticeable switching or ramping in current.

throttle pot fault protection
Definition: safety feature that shuts down motor operation during any open circuit fault.
Context: throttle pot fault protection protects the EV from accidental runaway by shutting the system down after detecting a fault in the system.