Are You Sure It's Shut Down? High-Voltage Battery Procedures

BY JASON DEFOSSE

HYBRID AND ELECTRIC VEHICLES ARE here to stay. Manufacturers are producing these vehicles more than ever before, and rescuers are scrambling to keep up with the ever-changing technology.

High-voltage shutdown procedures that isolate the power to the high-voltage battery have been taught for years now, but are they really effective? This article will cover what really happens when you turn off the ignition, disconnect the 12-volt battery, cut a first responder cut loop, or pull the service disconnect. Each of these shutdown procedures performs similar tasks but in different ways; some are more reliable than others but come with an additional risk to the rescuer.

High-Voltage Battery Review

Let's start by looking at how the power leaves the high-voltage battery in a hybrid or electric vehicle.

High-voltage relay. For power to flow out of the battery, the current must travel through a high-voltage relay inside the battery pack. This relay is powered by a 12-volt circuit; this 12-volt power must be supplied for the relay to operate and allow the electricity to leave the battery. The relay's operation can be simplified by understanding that, when 12-volt power is applied to the relay, the contactors in the relay close and allow power to flow. If 12-volt power is removed, the flow of high-voltage power from the battery is stopped because the contactor's open and the high-voltage power can no longer leave the battery.

12-volt battery disconnect. Many have been led to assume that, by disconnecting the 12-volt battery, power couldn't reach the relay and the relay would open. This makes sense in theory, but it fails to take the direct current (DC)/DC converter into consideration. Most hybrid and electric vehicles do not have an alternator to charge the 12-volt battery; instead, they use the DC/DC converter to accomplish the task of changing the low-voltage system. The DC/DC converter does exactly what is sounds like it does—converts high-voltage DC power from the battery to low-voltage DC to charge and maintain the 12-volt system in the vehicle.

Because of the function of the DC/DC converter, some vehicles will maintain complete low-voltage power even after the 12-volt battery has been disconnected. Unless the vehicle manufacturer directly advises that disconnecting the 12-volt battery will shut down the high voltage, do not rely on this method for high-voltage shutdown. The 12-volt battery should still be disconnected during the rescue assignment to ensure the security of the supplemental restraint system and the components within the vehicle.

First responder cut loops and disconnects. Many vehicle manufacturers have included low-voltage cut loops, plugs, or fuses for rescuers to use to isolate the power to the high-voltage battery (photo 1). These options allow us to directly interrupt the 12-volt's power being delivered to the relay. Once the circuit is interrupted, the relay is left without power, the contactor's open, and the power flow from the battery is stopped. Currently, there is no standard placement for these low-voltage disconnects, which can be found in a wide variety of locations including in the front of the truck (Tesla), the fuse box (Toyota), the engine compartment (Honda), and more. Responders should use the *Emergency Response Guide* or call the Energy Security Agency (ESA) for guidance on the location of the emergency disconnect.

Mechanical failure of the high-voltage relay. Before we move forward, we must address an issue that has been identified by many manufacturers. In a significant number of vehicles on the roadway, it has been determined that the high-voltage relay has a strong likelihood of failure. When this failure occurs, the high-voltage relay will weld itself in a closed position. In this position, high voltage will continue to travel outside the battery pack even after the 12-volt power has been isolated from the relay. In this scenario, the first responder cut loop, plug, or other low-voltage shutdown would not be effective in isolating the high-voltage power to the vehicle's battery pack. Keep in mind that there is no effective way to discern whether or not shutdown has been effectively completed.

(1) Photos by author.


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Service disconnects. The service disconnect is a high-voltage disconnection always located on the battery of the vehicle (photo 2). Unlike the first responder disconnect, this mechanism has direct interaction with the high-voltage system. Service disconnects located on the battery do not rely on the function of the high-voltage relay. Because these disconnects are located on the battery pack, when used, the rescuer must adhere to specific precautions during interaction. It is possible that high-voltage current is flowing out of the battery of the vehicle though this disconnect. If the current flowing though the disconnect is significant, it is possible for the user to experience "arc flash" or shock/electrocution.

To mitigate these possibilities, rescuers should ensure that the ignition is shut down and that no high-voltage components have been compromised to the point of dead shorting before using the high-voltage service disconnect. Rescuers should only interact with high-voltage disconnects when advised to do so by the ESA or the vehicle's *Emergency Response Guide*.

Stranded energy. Regardless of the procedure used to shut down the vehicle, energy will remain present in the high-voltage battery (photo 3). Identify the battery pack area of the vehicle early on and avoid it during your rescue assignment. In addition to the high-voltage battery, stranded energy may be present in other components of the vehicle outside the battery pack. This is typically found in capacitors and cannot be managed in the rescue environment. Because of this stranded energy and the possibility of high-voltage relay failure, treat all high-voltage components as energized at all times.

Considerations for Rescue Operations

Consider the following during your rescue operations:

1. Identify the vehicle early on (photo 4). Identifying the vehicle as *hybrid* or *electric* early in your assignment is important so that the vehicle can be managed appropriately. It is recommended to determine and then make it known to everyone on scene, even with internal combustion engines. Doing this will help you develop a habit of performing it at every vehicle response.
2. If the vehicle requires any extrication, has been exposed to large amounts of water, or is involved in a fire or the air bags have deployed, it is highly recommended that you conduct a high-voltage shutdown (photo 5).
3. Once the high-voltage shutdown is complete, inform everyone assigned to the incident. If it is not possible to conduct the shutdown, announce and confirm this to the rescue team.
4. During an extrication assignment, the rescue team should not interact with high-voltage components and should *never* manipulate the vehicle or any tool in a way that might damage the high-voltage battery.
5. If the high-voltage battery is damaged, rescuers must monitor the battery for steam, smoke, shorting, and fire. "Gurgling," popping, or other noises coming from the battery are an indication of thermal runaway and may indicate an impending fire event. A plan for rapid extrication should be made in case of fire.
6. If the high-voltage battery is damaged, monitor it for heat with a

thermal imaging camera. If the battery is found to be heating, cool it with water throughout the rescue assignment.

7. Some rescue operations will require the disruption of high-voltage components. Conduct evolutions that affect high-voltage components only after proper shutdown procedures are in place. The high-voltage battery should *never* be intentionally damaged during rescue operations.
8. If the battery has been damaged to the point where cells or pieces of the pack are found outside the vehicle, contact the ESA for guidance once the rescue assignment is complete.
9. If high-voltage shutdown is not possible, do not delay the rescue. Multiple shutdown options may be available.
10. Once the incident has been resolved, federal standards recommend that you conduct a risk analysis to ensure the vehicle will not pose additional risk to second responders or repair and storage facilities. The ESA offers this service for rescuers at no cost.

Shutdown Procedures Review

Hybrid and electric vehicles present different hazards than traditional vehicles. The following special considerations are necessary for safe interaction:

- Identify the vehicle early on and conduct the high-voltage shutdown procedures anytime the vehicle meets the criteria outlined in this training.
- If you cannot conduct high-voltage shutdown, do not delay rescue.
- Treat all high-voltage components as energized even after high-voltage disabling has been conducted.
- *Never* damage the high-voltage battery.
- If the battery has been damaged, monitor it for heat throughout the incident.
- Service disconnects are the most reliable form of high-voltage shutdown because they do not use the high-voltage relay.
- Ensure that the vehicle is safe for transport from the scene by conducting a risk analysis with the ESA.

With all the information provided in this article, it is important to understand that, although there is a lot of


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information available online, there is an equal amount of misinformation. It is my goal to clarify some best practices for an overall safer and effective rescue plan.

We can all agree that vehicle technology, especially in the electric hybrid vehicle market, is constantly changing and is the future as we attempt to reduce emissions and our carbon footprint globally. As rescuers, we need to be updating our skills and rescue tactics constantly. Familiarize yourself with first responder guidelines and resources from manufacturers or trusted first responder apps that you can download easily onto your smartphone or tablet. These can prove useful when interacting with electric and hybrid vehicles.

Understanding electric components, their locations and function, as well as battery location can help speed up our rescue time, resulting in better patient care and reduced injuries to both the rescuer and patient. Rescue is a game of inches, angles, and egress; if every action we take results in more space for our patient and medic, we cannot go wrong.

Remember, never use rescue tools such as rams or spreaders on the floors of these vehicles—this may create a thermal event, compounding your rescue assignment. Also be mindful of your cut locations and understand that the orange high-voltage cables do not share a standardized pathway.

Every vehicle is different. Understand that new vehicle construction is extremely robust and strong. In fact, when making relief cuts, we are no longer seeing a smooth reaction to the material but rather a more pronounced reaction, as new car construction no longer *cuts* but *fractures* and *breaks*. Education is the key. ■

Author's note: The ESA offers hybrid and electric vehicle training and real-time, on-scene guidance through its 24-hour call center; postcollision risk analysis; and a dedicated page where emergency response guides can be downloaded for free at energysecurityagency.com or (855) ESA-SAFE. Also, the National Fire Protection Association has a comprehensive list of emergency response guides available for download and offers training for hybrid and electric vehicle response at nfpa.org.

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