DC CONTACTOR RELAYS

Selecting High Voltage DC Contactor Relays




WHITE PAPER

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Speed to market can make or break a company's competitive chances in the global electric vehicle market. However, in the rush to entry, quality and functionality cannot be left behind. A deep understanding of the dos and don'ts with high-voltage DC relays can forestall preventable issues and enable a high-performance design that wins customer satisfaction. Consider these key factors during relay selection.

Introduction

In the race to electrify their vehicle designs, engineers may encounter applications having DC voltages higher than they are used to seeing. At these moderately higher voltages (48 to 1800 V), a properly selected contactor electrical relay can mean the difference between catastrophic failure and success. A proper system design will reduce the risk of a relay erupting, starting a fire, or disabling a critical function. Considerations include the relay technology, key specifications, and special problems of high-voltage DC applications.

Levitation

Levitation is a phenomenon that most vehicle designers have not had to plan for because it is rare in AC systems at typical vehicle voltages. In electric vehicles and electrified vehicle systems, the need to switch higher levels of DC power increases the risk of levitation in contactor relays. Levitation can occur during an overcurrent condition when the magnetic field created by the current is so strong that it pushes the moving contact away from the stationary contact, creating arcing and chattering. These may damage the relay to the point of catastrophic failure.

This unsafe event is a consequence of current beyond the specification for the relay. Engineers should know the level of current that could cause levitation and make sure the circuit will open before current reaches that point. Specify upstream circuit protection that will operate fast enough to prevent levitation in the relay.

Instead of a standard fuse, which is a thermal device that takes time to operate, a pyrotechnic safety module (PSM) offers high speed and can be a better option. Because of their higher cost, PSMs are usually limited to protecting the main battery disconnect.

Coordinated Circuit Protection

Circuit protection that is properly coordinated with the relay offers a balance between nuisance tripping and excessive contact arcing. However, a typical 4-5 millisecond differential might not be fast enough in some high voltage applications. Engineers should obtain the proper data from their relay and fuse suppliers and carefully coordinate circuit protection with the relay.

In addition, they should conduct testing of the relay and fuse combination to verify strong protection without nuisance tripping. Some component suppliers like Littelfuse have the facilities and expertise to provide magnetic modeling and physical testing for customers.

The easiest way to ensure coordination is to get advice from a supplier who manufactures both relays and circuit protection devices. Littelfuse can recommend proven pairings based on experience with many customer implementations.

Polarized High-Voltage Contactors

Polarized contactor relays have optimized magnetic blowouts that maximize arc quenching. Permanent magnets on the sides of the contact chamber create magnetic fields that bend the arc. By causing the arc to travel a longer distance, resistance is increased, and the arc extinguishes faster.

Polarization greatly improves the make/break capability and cycle life. Polarized contactors have twice the cycle life of non-polarized contactors in high voltage relay applications.

Polarized contacts are designed to work with current flowing from the positive input to a negative output. If the relay opens on a circuit with the current reversed, cycle life is significantly reduced. Therefore, a non-polarized conductor is appropriate in applications where the current flows frequently in the reverse direction. Nevertheless, a polarized DC contactor is usually the better choice for HV EV applications of greater than 350 V due to higher cycle life.

More information on this subject and other points of contactor design are available in our application note: "Contactors for High Voltage Electric Vehicles."

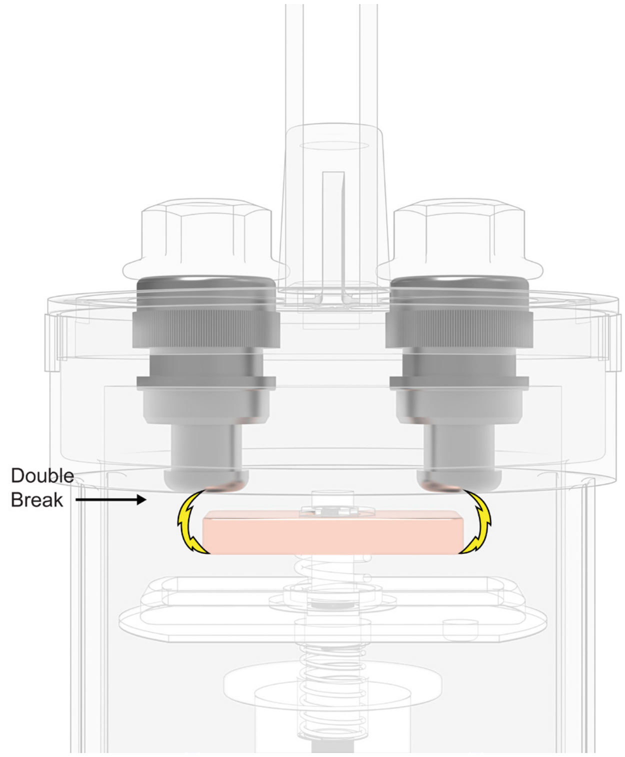


FIGURE 1. Polarized contactor relays use magnets to bend the arc, which increases resistance because the arc travels a longer distance. In addition, a pair of contactors divide the arc current in half.

Types of Solenoid Relays

Solenoid style relays are available in a variety of coil types and options. The optimal type depends on the application within the vehicle and special concerns of high-voltage DC systems.

Monostable relays (also referred to as normally open relays) turn on when the coil is On and turn Off when the coil is Off. They have one position (usually Off) that they return to when the coil is turned Off. This type of relay is usually designed to control a specific load that is turned On and Off as needed in the vehicle.

Bi-stable relays (or latching relays) are designed to stay in either the On or Off positions with no power applied. The plunger in the relay is held in position by a mechanical or magnetic latch.

A familiar example of mechanical latching is the mechanism of a retractable ballpoint pen, where the user pushes to move the ballpoint out of the housing and pushes again to retract the ballpoint. The point remains in either of two stable states until the user presses the actuator.

In standard solenoids or relays, a control current has to be maintained in order to keep the plunger in the On position. In a bi-stable relay, the control current is only applied when changing between the two states of Off and On. Because no current is used in the On or Off states, bi-stable relays generate less heat and consume less power.

An economizer is a circuit made of electronic devices on a printed circuit board that is added to a single coil relay. It controls the flow of power to the solenoid so that a large current overcomes the force of the spring to move the plunger and a small current holds the solenoid in position. This strategy reduces energy consumption.

A dual coil relay achieves the same result by using two coils: one to overcome the force of the spring and another for holding. The holding coil uses less power.

Economizers and dual-coil relays are designed for relays that will remain in continuous service rather than intermittent duty. In continuous service, relays without an economizer or dual coil design become hot during normal operation because the full current is applied continuously. This heat is a sign of energy loss.

Avoid Bi-stable (Latching) Relays in High Voltage Applications

With an internal combustion engine, the electricity generated is almost 'free' in that it is a byproduct of another process. In designing an electric or hybrid electric vehicle, the attitude is very different. A great deal of engineering is concerned with energy efficiency. Naturally, design engineers want to select relays that minimize energy consumption. However, in high voltage applications, selecting a bi-stable (latching) relay is a risky strategy.

When power is removed from the relay, the ground may pull off before the power is removed, causing the latch to stay closed. This can cause a catastrophic situation because the function controlled by the relay won't stop or because the relay will be left unexpectedly in the On position when the vehicle is restarted.

In contrast, a monostable relay automatically opens when the power is removed. In high-voltage DC applications, it is risky to select any other style of relay.

Make/Break Chart

Relays having higher voltage ratings tend to cost more and be physically larger because they require larger contactor surface area and more robust construction. Engineers may reduce relay cost and size by specifying a relay with a lower nominal or continuous rating if the relay will experience a higher-than-rating voltage only rarely. This is the case if the relay doesn't open or close with a load on it, or the vehicle is usually shut down before the relay is opened.

For example, a design engineer can safely specify a nominal 500 V or 800 V relay if it will see 1000 V only a few times over the course of its operation compared to thousands of operations at 500 V. In application, the relay might make or break a connection at 1000 V only 50 times in its entire operational lifespan.

While the maximum voltage rating of the relay is the ceiling, designers can trade voltage rating for duty cycles. To aid in this decision, designers can consult the relay manufacturer's make/break chart. This chart shows the number of make/break cycles a relay will perform at each voltage.

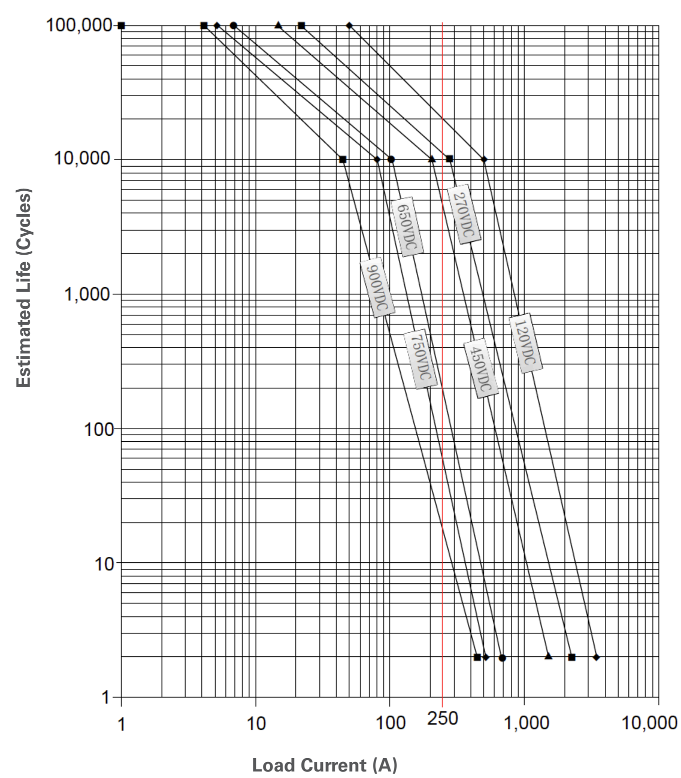


FIGURE 2. Example make/break chart.

Why Relay Voltage Ratings Are Important

When using a relay at a higher voltage than its rating, the main problem is arcing. The higher the voltage, the more arcing that will occur and the longer the arc lasts.

Electrical arcs are essentially as hot as the surface of the sun. The heat generated by the arc damages the metal contacts, causing pitting. After a certain number of cycles, the metal will be so pitted that the relay may fail.

Also, the arc develops a plasma that leaves a vapor deposit of metal on the sides of the contact chamber. This may lead to a phenomenon called "arc tracking" in which a short circuit develops from the moving contact to the stationary contact.

Operating a relay at voltages higher than its nominal or continuous rating increases the risk of failure from pitting and tracking. The purpose of a make/break chart is to help the design engineer see how many operations at higher voltages can be tolerated by a specific relay and specify the lowest rated relay for the expected number of lifetime cycles at each expected voltage level.

About Littelfuse

Littelfuse is passionate about working with customers to create products that protect, control, and sense for a safer, greener, and more connected world.

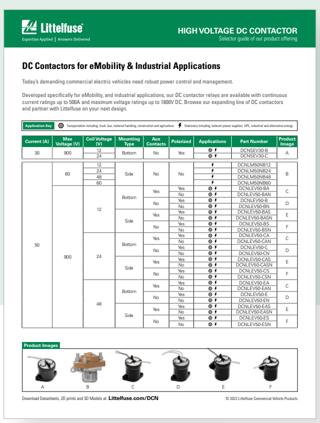
Through its Commercial Vehicle Products (CVP) business unit, Littelfuse is expert in electric vehicle applications. By offering a growing range of high-voltage DC contactor relays along with the broadest portfolio of ancillary components, and by applying deeper knowledge of high-voltage and automotive applications, we help busy engineers make more reliable designs and get them to market faster.

Customers can source multiple components from one supplier, receive answers quickly, and easily source sub-assemblies like customized power distribution units. No other supplier can easily and quickly integrate switching relays, fuse, sensor, and PSM into a customized subassembly.

With magnetic arc blowouts, coil economizers, and polarized and non-polarized options, our high-voltage DC contactors are safe, reliable, and efficient.

View our DC Contactor Selection Guide:

www.Littelfuse.com/DC-Contactor-Selector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