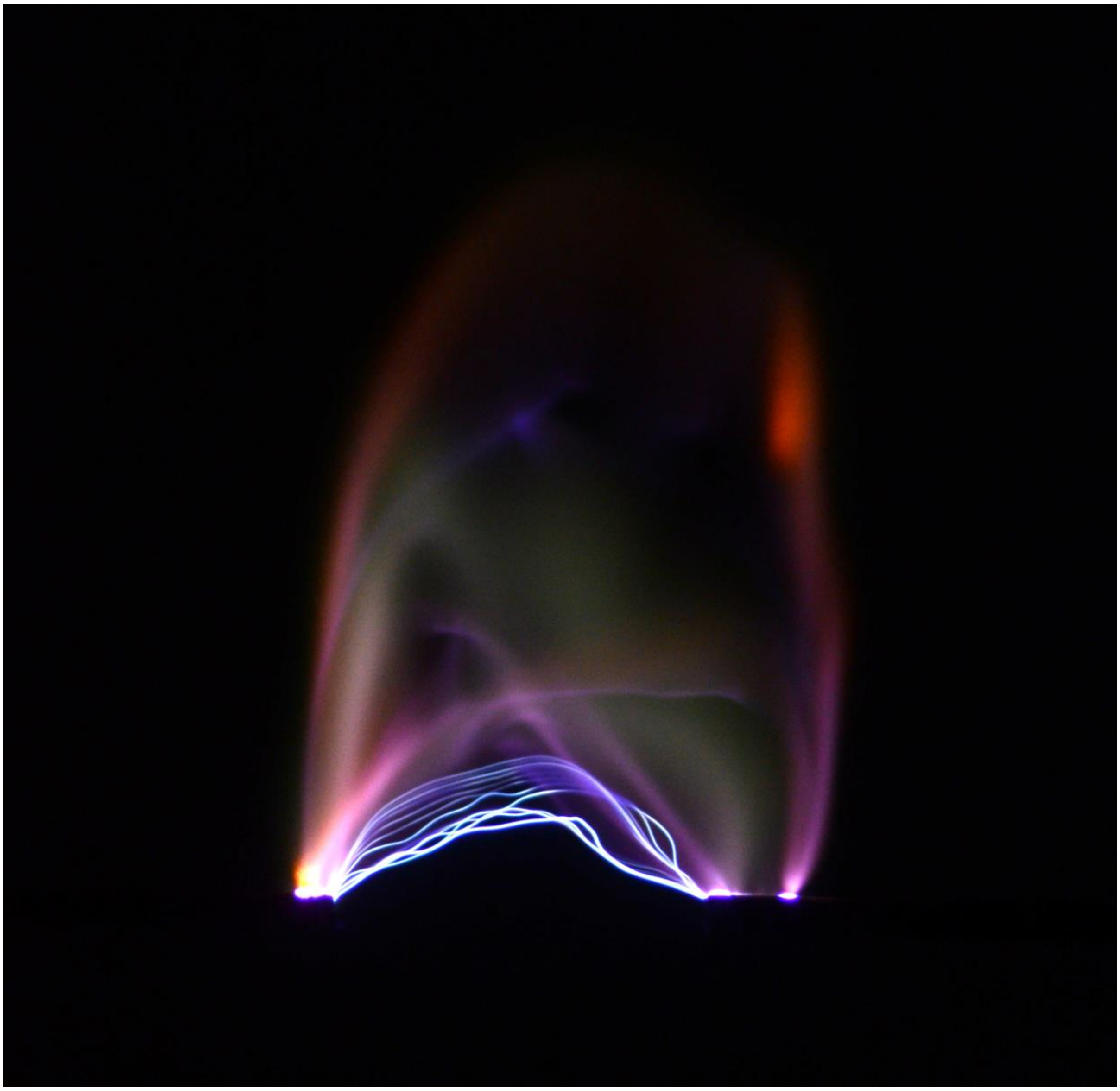
The right choice of relay for higher DC loads

Outsmarting the DC switch arc

Electromechanical relays (EMRs) or solid-state relays (SSRs) are used for switching various loads in numerous industrial fields. These switching devices generally operate reliably in the control cabinet at the most commonly used voltage levels – 24 V DC and 230 V AC. If, however, DC loads have to be switched at higher voltages, often with higher powers at the same time, the common standard versions of the EMRs and SSRs prove to be unsuitable, and often fail quickly. (Lead).



Applications for the switching of higher DC loads can be found in numerous industrial sectors. In many of these applications, they are frequently used, which is why development engineers and planning offices are familiar with them. Examples include electric motor vehicles with up to 800 V DC, battery voltages on trains with their country-specific 72 V DC, 96 V DC or 110 V DC, and photovoltaic systems with up to 1000 V DC. Due to the application-specific switching requirements and the simultaneously occurring high currents, the relay manufacturers have developed special relays for those applications (figure 1). However, these devices are often unsuitable for the control cabinet applications implemented in automation solutions.

Figure 1 - Power relay for DC loads of up to 200 A, for use in electric forklifts, as an example

Direct usage of DC voltage from battery systems

For the most part, the control cabinets in industrial automation solutions use the common control voltages of 24 V DC and 230 V AC as well as three-phase systems for mainly motor-driven applications, operating at higher voltages. At a closer look, however, also DC voltage systems operating at more than 100 V DC can be found, normally used as battery-based emergency power supplies in case the mains voltage fails. Such solutions are used in computer centres, airports, in the chemical industry, in process engineering, in power plants for electricity generation, etc. Let's take this last-mentioned application as an example for a more detailed explanation.

To maintain uninterrupted operation even when a malfunction occurs, power plants have emergency power generators. When these also fail, large battery systems need to ensure that the important parts of the power plant can operate in emergency mode for a certain time. In Europe, such applications preferably use 220 V DC battery systems, whereas also 110 V DC and 125 V DC solutions can be found in other parts of the world. In order to supply the very high power required, a significant number of individual cells is connected in series as well as in parallel to a large battery system. Numerous loads from the control system, including many switching devices such as contactors and coupling relays, which are conveniently snapped onto standardised DIN rails in the control cabinet, are directly supplied by the DC voltage from these batteries. In contrast, three-phase loads – such as pumps – are supplied indirectly by the batteries via rotating transformers or converters.

No voltage commutation with DC voltages

Yet what are the reasons that cause the standard coupling relays in such applications, often installed due to a lack of ignorance, to fail so quickly, as described above? The answer can be found considering the completely different behaviour of coupling relays when switching AC or DC voltage. On that point, a brief digression into the physical basics: Almost all of the standard coupling relays available today have contact clearances in the range of 0.3 to 0.4 millimetres. These clearances are perfectly sufficient to switch off loads up to 230 V AC, even at higher currents. Not later than after one half-wave of the sinusoidal mains voltage, the voltage commutates and thus ensures that any electric arc possibly igniting at shutoff is extinguished automatically. Naturally, with DC voltages, there is no voltage commutation, which is why the maximum permissible switching current decreases drastically, especially with higher switching voltages. AC and DC switching behaviour is often shown in a diagram, and the curves are designated as load limit curves (figure 2).

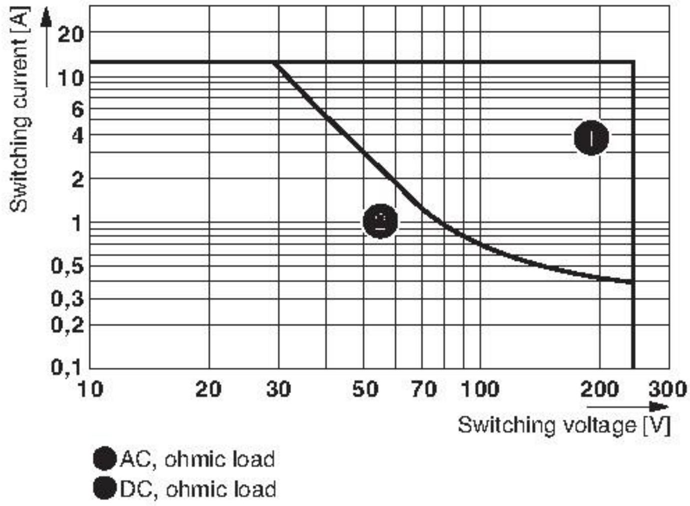


Figure 2 - Strongly different load limit curves of a standard coupling relay for contact-side switching of AC and DC loads

Generally, users don't know about the differences in relay behaviour because the interruptible current – see the diagram in figure 2 – turns out to be absolutely identical (10 A, refer to the example of the 10 A coupling relay) at the voltages of 24 V DC and 230 V AC commonly used in automation solutions. However, in applications where the DC voltage to be switched is significantly higher – 220 V DC, for example –, the 10 A coupling relay can only switch off 0.3 A. This is why, unfortunately, misuses occur frequently, leading to a total failure of the standard coupling relays, sometimes even during the first switching cycle. Figure 3 gives a good impression of what happens when the load – only 220 V DC/1 A in this case – is clearly above the DC load limit curve according to the diagram in figure 2 (figures 3a to 3c).

Figure 3a - No problems yet: The relay is active, the N/O contact (right side) is closed, and the load current flows

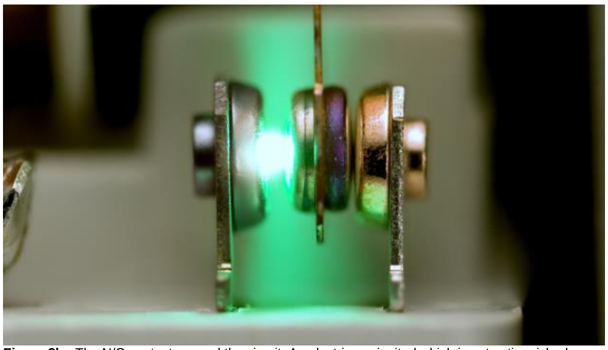


Figure 3b - The N/O contact opened the circuit. An electric arc ignited which is not extinguished because of the DC load that is too high. The contact therefore tarnishes after a short amount of time already, due to the extreme heat.

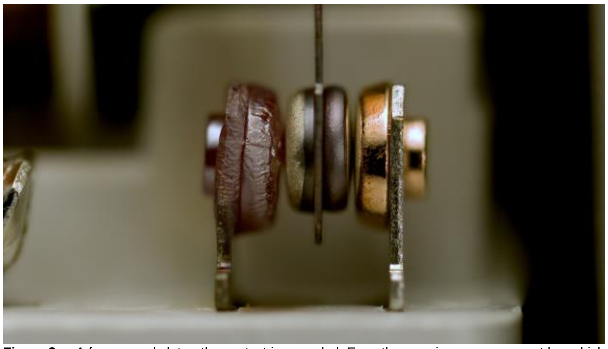


Figure 3c - A few seconds later, the contact is annealed. Even the massive copper current bar which it was riveted into became plastic and dropped on the other contacts. The relay has thus been destroyed during one single switching cycle

Integration of an additional magnetic arc blowout solution

The explanations above emphasise that common coupling relays are not suitable for switching off higher DC loads. Consequently, automation applications also require special solutions. The integration of an additional magnetic arc blowout solution has proven to be helpful here. The functional principle is simple: A permanent magnet is integrated into the contact gap of such a special relay. Any electric arc igniting at shutoff will now be deflected in the magnetic field in accordance with physical laws. Instead of, as before, striking directly at the point where the distance between the opened relay contacts is shortest, the electric arc deviates laterally between the contacts. Because this looks like the electric arc is blown out of the gap, the relays are called magnetic arc blowout relays (figure 4). The electric arc becomes significantly longer and even the higher DC switching voltage is not sufficient anymore to help maintaining it therefore the electric arc extinguishes within a few milliseconds. Usual coupling relays of such type safely switch off loads up to 220 V DC and 10 A, as shown clearly in their load limit curve (figure 5). After all, this value is 30 times as high as for relays of the same design without blowout magnet.

Figure 4 - Conventional coupling relay with blowout magnet for high DC loads, for mounting on a DIN rail

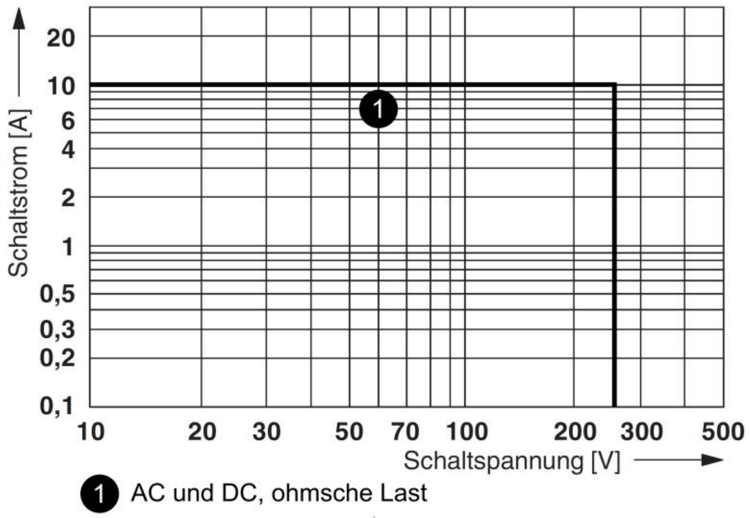


Figure 5 - Load limit curve of a relay with integrated blowout magnet having basically the same design as the relay without blowout magnet, the load limit curve of which is shown in figure 2

Purely electronic switching by high-voltage MOSFETs

Another interesting alternative for switching loads at higher DC voltages is the use of modern solid-state relays (SSRs). The key here is the use of modern high-voltage MOSFETs. So, up to voltages of 300 V DC, switching is done electronically, with no electric arcs ever occurring. Consequently, there is no wear either. Such devices outperform electromechanical relays not only with regard to their service life: They don't bounce, and moreover, switching is fast and completely silent. An especially narrow version from Phoenix Contact's PLC product family is shown as an example in figure 6. Even if the solid-state relay can “only” switch loads of up to 300 V DC/1 A, it tops conventional standard relays by a factor of 3 to 5 while offering the above-mentioned advantages. Moreover, the SSR has proven to be space-saving with its overall width of only 6.2 millimetres.

A third approach to the switching of higher DC loads is the contact series connection of several N/O contacts or N/C contacts of a conventional multi-position coupling relay. Depending on the number of contacts connected in series accordingly, DC switching currents in the low one-digit ampere range can be reached at a switching voltage of 220 V DC. Information on the interruptible current is provided in the relay manufacturer's load limit curve, if determined for this special type of connection.

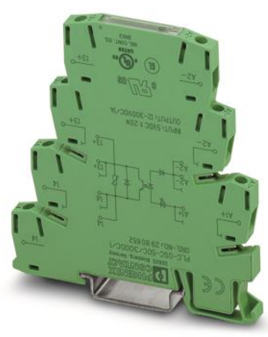


Figure 6 - The solid-state relay for up to 300 V DC / 1 A is narrow, wear- and bounce-free, and causes no electric arc.

Summary

Trouble-free switching even of higher DC loads up to 250 V DC and 10 A can be realised by means of selecting a special coupling relay, preferably with blowout magnet. The use of these powerful devices eliminates the need to expect troubling failures such as those occurring in similar applications with conventional standard relays, where continuous electric arcs occur. In applications with switching voltages of up to 300 V DC as well as maximum currents of 1 A, the high-voltage SSR presented can be an interesting alternative to its electromechanical equivalent. This is because it's only as wide as a terminal block with its overall width of 6.2 millimetres, and it switches completely wear-free.

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