Shrinking the Footprint of High-Current Switching

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With electrification comes rising demand for compact, efficient, and resilient power control systems, from utility-grade installations and industrial drives to consumer EV charging units

Power control is a critical aspect of the electrification trend, expanding demand for improvements, upgrades, and modernisation throughout infrastructures from solar and wind generators to points of use. Equipment targeting residential applications faces intense cost pressure, with demands for miniaturisation to allow unobtrusive and fashionable styles. On the other hand, reliability and fault handling are dominant requirements in industrial electrification, while advancements that improve efficiency are wanted everywhere.

High-Current Switching

When it comes to handling high currents and voltages, electromechanical switches including contactors and relays are chosen for their high ratings and ability to safely isolate inactive loads. Contactors tend to have larger electromagnetic coils than relays as well as spring-loaded contacts for breaking the circuit and have been preferred in applications that involve controlling extremely high currents. Contactors have also tended to contain built-in weld detection that can protect the system if the main contacts become fused and fail to open when required. This is typically implemented with a set of auxiliary contacts that mirror the main contact structure.

With their auxiliary contact mechanism, higher coil rating, and spring loading, contactors tend to be physically larger than ordinary relays and can support lower maximum switching frequency. Interconnection typically relies on screw terminals, which require manual assembly. In today's electrifying world, new DC-switching applications include large inverters for utility-grade photovoltaic generators and battery-energy storage systems, high-speed electric vehicle chargers and domestic wallboxes, and uninterruptible power supplies (UPS). These are disrupting the old order, demanding high current capability and safety features of contactors, smaller size, and lower power consumption, in a device compatible with high-volume production techniques. Similar pressures apply to more traditional AC loads such as lighting, HVAC and FA, where power density is increasing and demand for smaller and compact devices becomes a necessity.

Relays Step Up

New developments among relays allow current ratings in the 50A-300A range, which lets these devices offer an alternative to contactors in many domestic, industrial, and utility-grade applications. The latest devices also feature weld detection with fault signalling thereby permitting comparable system protection. The auxiliary contact mechanism shown in figure 1 ensures safe insulation, with a withstand voltage of 2.5kV or minimum contact gap of 0.5mm, even after the coil is de-excited when the main contacts have a welding failure.

Among the inherent advantages of relays, smaller component dimensions permit more compact and lower-profile enclosure sizes. This can be important for consumer markets that desire fashionable and minimalist styles to industrial and utility applications challenged to install more and smarter infrastructure within existing space constraints. Contrasting the properties of a typical contactor with a comparable relay reveals more than 66% weight saving, as well as more than 60% less height and 85% lower volume.

The relays' smaller size and typically lower weight permit PCB mounting of high-power switches that can simplify and streamline equipment assembly. PCB-mounted components are compatible with automated production processes, allowing circuits to be assembled at high speed using inline insertion equipment. Subsequent automated soldering lets equipment vendors design-out traditional bulky and expensive components such as busbars and screw terminals that need to be manually fastened. In addition to permitting faster and more efficient assembly, soldered connections save human errors such as incomplete screw tightening or applying incorrect torque,

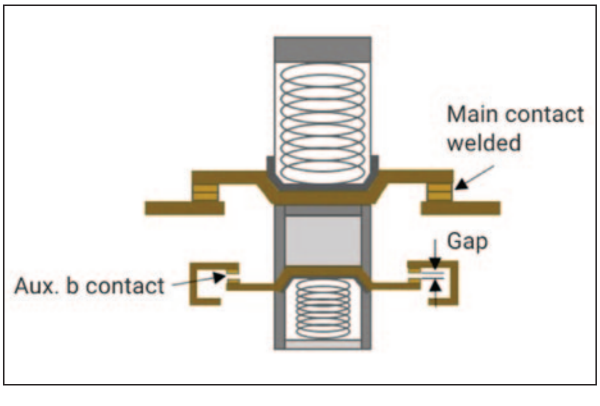
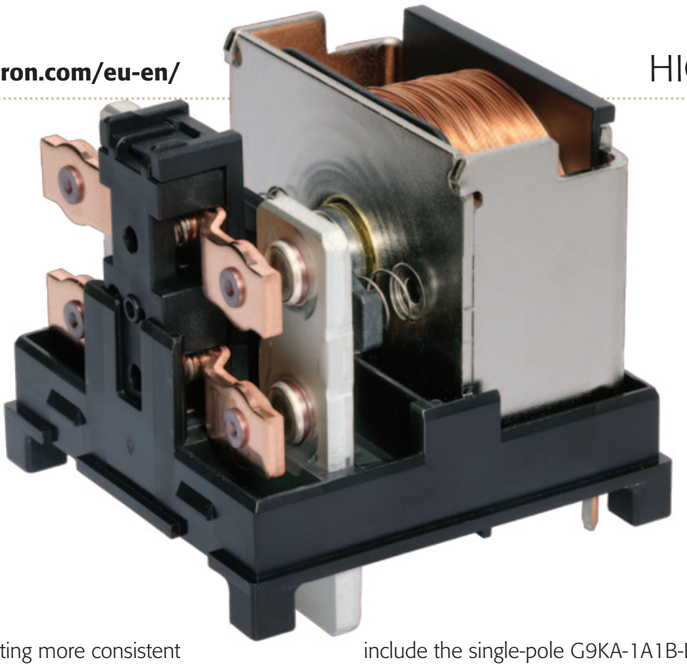


Figure 1. High-current relays now incorporate auxiliary contacts for fault detection.



permitting more consistent production quality.

On-Boarding

Moving established design practices and production flows away from traditional manually installed contactors to PCB-mount relay assemblies involves literally going back to the drawing package to create a new circuit-board design. PCB design guidelines include ensuring adequate copper thickness to carry the intended current, noting that enlarging the terminal surface area can help boost heat dissipation. A heatsink or insulated metal substrate can help protect the board in applications that demand extremely high current. In addition, for high-capacity PCB relays, implementing a holding-voltage circuit or PWM drive circuit to minimise power consumption can effectively ease thermal management and can potentially reduce the drive power to 25%. Equipment vendors can recoup the investment to redesign their PCBs through greater saleability, delivering smaller, lightweight PCB-based assemblies that fulfil market desires.

The production area may also need to be reorganised to reduce or remove manual workstations and migrate production onto automated machinery for through-hole assembly. A comparison of production techniques suggests that soldered terminals can reduce the bill of materials (BOM) including busbars and screws by up to 35%, while assembly-process costs can be reduced by as much as 50%. The benefits gained through automated assembly become more significant as production is scaled to larger volumes.

In addition, changing to PCB relays can enhance product performance and improve energy efficiency. The lower contact resistance of these relays leads to reduced I2R losses and heating thereby extending contact reliability. In addition, the coil power is lower, contributing further to increased efficiency.

OMRON's high-current PCB relays include the single-pole G9KA-1A1B-E, which can carry up to 300A and has main contact resistance less than 0.2mΩ. The design of the mechanism and the materials selected contribute to the low resistance and also permit a contact gap of 4.0 mm ensuring high performance with safety. There is also a 30V/1A mirror contact structure built-in to provide weld detection meeting IEC 60947-4-1, the international standard for electromechanical contactors and starters including motor protective switching devices.

Overall, while moving to PCB-mounted solutions requires upfront investment, vendors gain significant long-term payback in cost, efficiency, and reliability.

Conclusion

Electromechanical contactors are historically accepted as the kings of high-current switching, covering a wide range of ratings up to hundreds of Amps. While their strengths also include auxiliary fault-detection contacts, there are disadvantages. Devices tend to have a large and heavy coil and contact mechanism, which adds bulk and limits switching frequency, while manual assembly methods slow production and allow scope for human error.

New demands arising from electrification are driving innovations in PCB relays that elevate current-handling capability and provide built-in fault detection, presenting a new option in the 50-300A range that permit more compact, reliable, efficient, and cost-effective power control.