Whitepaper

Powering success:

Mastering the art of integrating relays and contactors that are reliable and safe

Relay & Contractor Solutions

Index

Executive summary

Authored by Jürgen Steinhäuser

The relay and contactor industry has experienced significant technological advancements over the past decade, mainly driven by energy generation, distribution and storage changes. The rise of Direct Current (DC) loads due to increasing energy efficiency demands and the expansion of DC grids have necessitated the development of advanced relay products. Hybrid relays, which combine electromechanical switching elements with semiconductor switches, are emerging as key solutions to handle higher switching loads in these applications.

Key integration challenges

Some of the key challenges industries have faced when integrating relays and contactors have been primarily due to the growing use of DC grids, which differ significantly from traditional Alternating Current (AC) grids. DC systems lack the natural arc-extinguishing, zero-crossing point, presenting a greater risk of arc formation at high voltages and currents. Relays are critical in addressing these issues, providing essential isolation elements that improve overall system safety.

Another important influencing factor is urban densification. In the future, more people will live in less space. Public transport will replace private transport and single-family homes will increasingly be replaced by energy-efficient and resource-saving apartment buildings. None of this will be possible without further digitalisation.

Faster boarding and alighting times on trains and more trains with less distance between them will be just as necessary. Complex climate control, energy management and, thinking even further ahead, urban agriculture will require sophisticated irrigation and lighting, among other things. To make this energy-efficient, relays are needed as electrical isolating elements which, unlike semiconductors, guarantee a real power interruption. This requires a large number of low-consumption and compact relays.

Emerging trends

It is not yet possible to predict which relays will be needed in the future. The trends described above are clear, but it is only partially possible to recognise what form the respective switching tasks will require. Development is progressing rapidly and it is exciting to see what projects are currently being researched. However, it is very clear that sustainability in a resource-conserving world worth living in is inconceivable without (new) relays.

Introduction

This whitepaper provides industry professionals, engineers and decision-makers within the industrial sector with a comprehensive overview of relay and contactor technologies. This includes force-guided safety relays, automotive relays, high-voltage DC contactors (HVDC), low-voltage DC contactors, industrial relays, solid state relays (SSRs) and solenoids.

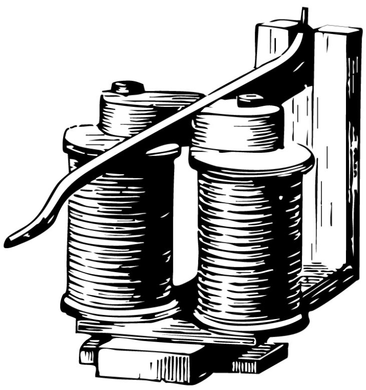
By examining the trajectory of relay technology, we highlight the ongoing importance of these devices in an increasingly electrified world. As industries continue to evolve with growing demands for efficiency, miniaturisation and intelligent control, understanding the capabilities and potential of relay technologies becomes crucial for driving innovation and addressing future challenges in electrical engineering and related fields.

Chapter 1:
The electrifying journey of relays and contactors

Relays and contactors encompassing all technology types are fundamental components in modern electrical systems, enabling the control and protection of circuits and machinery across industries. Their origins trace back to the late 19th and early 20th centuries, coinciding with the widespread adoption of electrical power for industrial, commercial and residential applications.

Origins of relays and contactors

The first functional relay was invented in the 1830s by American scientist Joseph Henry, who designed an electromagnetic switch to amplify weak electrical signals, primarily for controlling telegraph signals. The advent of AC systems by pioneers like Nikola Tesla and George Westinghouse transformed relays and contactors into integral components of electrical infrastructure.



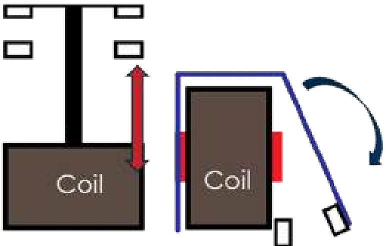
First functional relay style

As industries sought more efficient ways to manage complex electrical systems, the need arose for devices capable of handling high-current switching and offering remote control over industrial equipment. This led to the development of contactors - specialised relays capable of handling larger electrical loads and used for switching high-voltage circuits.

By the early 20th century, industries demanded more robust devices for switching AC and DC motors, transformers and other power equipment, solidifying the role of contactors in power distribution and industrial automation.

Early applications and industries

From their inception, relays and contactors played a crucial role in expanding electrical power applications. Early use included telegraph systems and railway signalling where reliable, remotely operated switches were essential.



The Industrial Revolution accelerated their adoption as large factories required solutions for controlling lighting, machinery and power distribution. Relays were soon employed in telecommunication equipment and subsequently in the control systems of power plants, transformers and electric motors.

Whilst relays and contactors emerged from telecommunications, solenoids - coils of wire generating magnetic fields to create mechanical motion, were first used in textile machines. As Paolo Waldis, Director at Italiana Relè, notes: *"The textile industry and vending machines traditionally were early adopters. More recently, the automotive industry has influenced development requiring smaller components."* The automotive industry initially functioned without relays, but as vehicle electronics became more complex, relays became essential for managing functions with miniature, lower-current switches. Another critical early innovation was force-guided safety relays, ensuring fail-safe operation in railway signalling systems of the 1940s and 1950s.

Solenoid

By the mid-20th century, relays and contactors were widely used in mining, steel production and commercial construction, where their reliability and efficiency proved invaluable.

Key technical developments

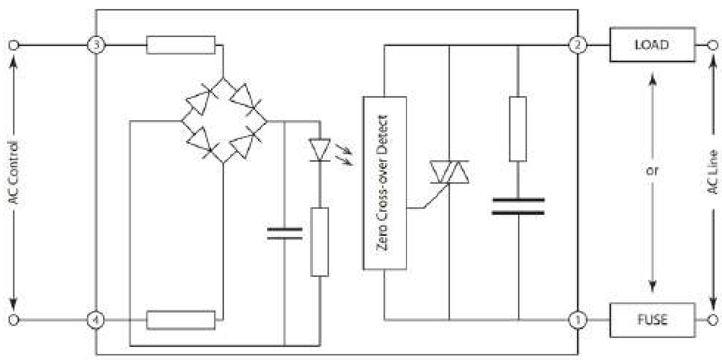
The early development of relays and contactors has been marked by significant technology advancements.

John Merrill, an expert in relays with over 40 years' experience, points out that: *"Early relays used resin-impregnated paper and similar materials for insulation, making them physically large and bulky. They were primarily used in telecommunications and basic vehicle electrics."*

As demand grew for smaller, more powerful devices, advancements in materials science and electromagnetic theory enabled miniaturisation. As John Tribe, Sales Director at Foxtam Controls explains: *"Miniaturisation has been the biggest advancement. Customers adopted the four-pole industrial relays, which offered the same performance in a compact package."*

In the 1970s and 1980s, improvements in coil windings, insulation and contact materials allowed relays to handle higher currents while maintaining durability. Ricardo Esquinazi, Brand Manager at Durakool, highlights a major milestone: *"Although railways were using DC relays as far back as 1879, in 1954, the first High Voltage DC (HVDC) transmission link between Sweden and Gotland Island changed electricity transmission methods worldwide."*

The 1960s and 1970s saw the emergence of solid-state relays (SSRs), replacing electromechanical components with semiconductor materials. Early solid-state relays were primarily designed for AC switching applications. These relays offered faster switching, greater reliability and eliminated mechanical wear and tear. Merrill adds: *"Early AC switching types used thyristors, later incorporating triacs or transistors. High-current DC solid-state relays only became practical after power MOSFETs were developed."*



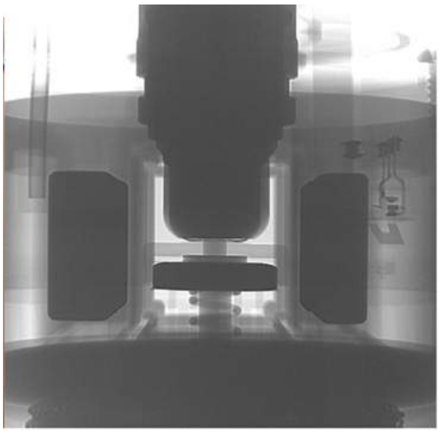
Single phase Solid State Relay Circuit

Force-guided relays gained prominence in industrial machine safety, emergency stop circuits and press control systems by the 1950s and 1960s. In the 1970s and 1980s, their use expanded to nuclear and energy sectors, ensuring absolute reliability in power distribution and reactor control. By the 1990s, they were integrated into medical equipment, such as ventilators and radiation therapy machines, where precision and safety were paramount. As Merrill explains: *"The origin of sealed HVDC contactors for military applications, particularly submarines, can be traced back to as early as WW2."*

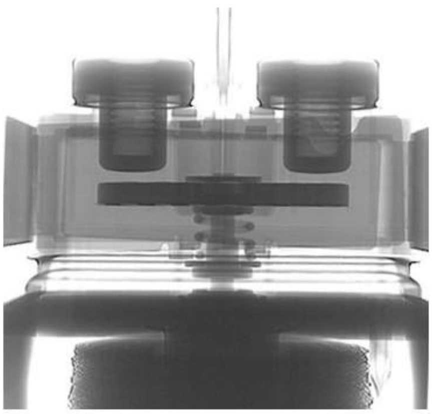
The 21st century has ushered in digital integration in relays and contactors. Modern relays are now part of a larger network of interconnected devices. Industry 4.0 and the Internet of Things (IoT) enable remote monitoring, predictive maintenance and automated electrical system control. These digital relays and contactors feature software algorithms for diagnostics, power optimisation and fault detection.

A key innovation in this era is the Controller Area Network (CAN) protocol, developed by Bosch in the 1980s. Before CAN, automotive systems relied on complex wiring. The CAN protocol standardised communication among electronic control units (ECUs), reducing wiring complexity and improving real-time data exchange. By the 2000s, CANBus technology had become the industry standard for vehicle communication, influencing the development of CAN-compatible relays.

Modern material innovations have also transformed relay and contactor performance. Waldis emphasises: *"The introduction of advanced plastics was crucial for solenoid development specifically."* Esquinazi adds: *"For HVDC contactors, sealed chambers with inert gases and blow out magnets, along with improved contact materials, have allowed us to handle higher voltages and currents with minimal heat losses."* He further explains: *"HVDC contactors operate based on Faraday's law. Advances such as square coils and optimised core materials now generate the same electromagnetic force in a more compact design with fewer heat losses."*



Xray image - epoxy HVDC Contactor



Xray image - ceramic DC Contactor

Evolution of safety standards and regulations

As relays and contactors became essential in critical infrastructure, safety standards and regulations evolved to ensure reliability and longevity.

Early standards such as the National Electrical Code (NEC), established in the 1910s, focused on basic electrical safety. In the latter half of the 20th century, global organisations like the International Electrotechnical Commission (IEC), developed rigorous standards including IEC 60947-4-1 for contactors and IEC 61810 for relays. These outlined electromagnetic compatibility, durability and load-bearing tests, to meet modern electrical system demands.

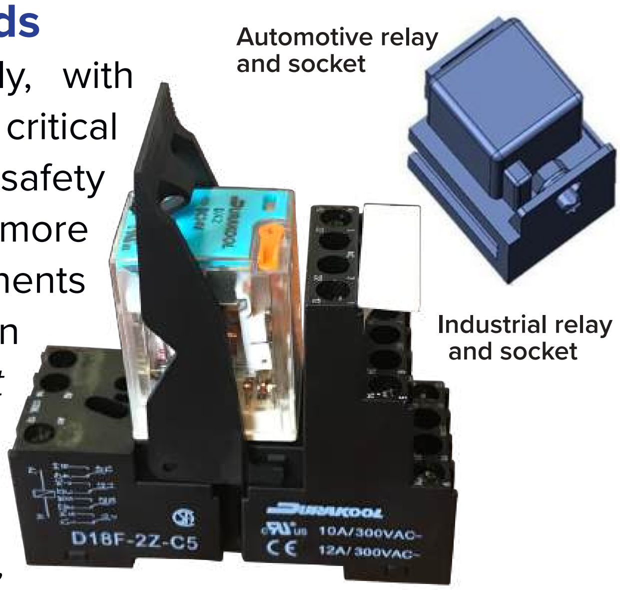
Today, safety features such as arc suppression, overload sensing and remote monitoring are critical elements of modern relays and contactors. In industries like renewable energy, automotive and industrial automation, regulations mandate fail-safes and diagnostics to mitigate electrical hazards. Esquinazi comments: *"Higher-voltage DC systems in solar fields and electric vehicle infrastructure require stringent safety measures to prevent arc flash and shock hazards."*

Manufacturers now integrate advanced protective functions including surge protection, fault isolation and even fire resistance, to meet international safety certifications such as UL (Underwriter Laboratories) certification and CE marking, ensuring compliance environmental and quality standards.

Chapter 2:
Navigating today's relay and contactor landscape

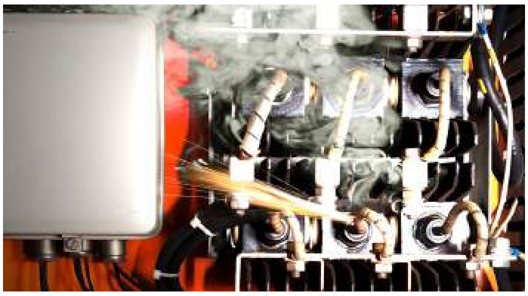
Industry evolution and market demands

The electric world has evolved significantly, with relay and contactor technology playing a critical role in power distribution, motor control and safety systems. As manufacturing processes become more sophisticated and demanding, these components have adapted to meet modern demands. John Tribe comments: *"Customers often expect suppliers to offer a full range of plug-in relays and sockets, complimented with timing relays, monitoring and control relays, supplied as a package – they go together like fish and chips!"*



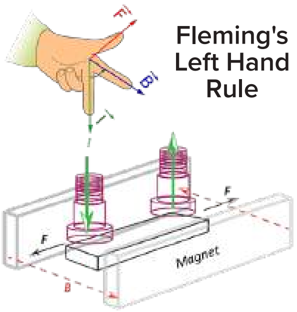
Technological convergence and arc control

Relay and contactor technology blends traditional electromagnetic principles with digital advancements. Modern devices feature enhanced durability, improved energy efficiency and sophisticated monitoring capabilities.



Contactor fire - no blowout magnet

Arc control is a key area of development, particularly for high-power applications. Alex Ramji, Director of Product Management at Nuvation Energy, notes: *"It's common to hermetically seal contactors to remove contaminants and reduce the threat of arcs. Magnets are also used inside the contactor to push the arc across and dissipate heat."*



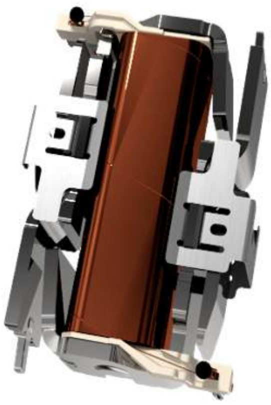
Arc temperatures can exceed 10,000°C, posing risks of explosion if not properly managed. Blowout magnets generate a magnetic field to divert and extinguish arcs quickly, reducing wear, preventing equipment damage and enhancing electrical devices' overall safety and longevity.

Solenoid-relays use electromagnetic force to minimise arcing duration by rapidly opening or closing contacts. Paolo Waldis highlights key differences: *"AC and DC solenoids adopt different plunger designs - AC solenoids can even use laminated frame construction for efficiency, while DC solenoids normally rely on solid plungers and steady magnetic fields."*

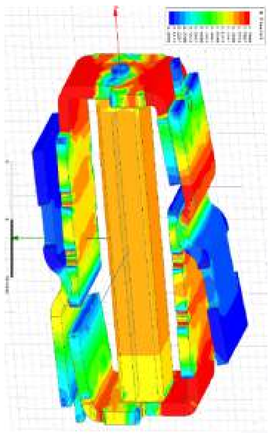
Advanced contactor designs also enhance arc suppression. Optimised rivet quality, curved contactor shapes and double contact gaps extend arc paths, increasing resistance and cooling the arc. While AC arcs self-extinguish at zero crossings, DC arcs persist, requiring wider contact gaps, inert gases and magnetic arc blowouts to ensure safe operation.

Digital integration and miniaturisation

IoT-enabled relays and contactors are transforming industrial automation by enabling real-time monitoring, remote control and predictive maintenance. Concurrently, miniaturisation continues to push the boundaries of design with new devices maintaining high performance whilst requiring significantly less panel space. Signal relays have become significantly smaller in size offered in surface mount (SMT) packages.



Rectangular coil bobbin



Magnetic flux model

Among industrial and automotive relays, complex metallic alloys and surface coatings have reduced contact resistance, allowing for smaller contacts without compromising performance. Innovations in magnetic characteristics and flux polarisation have reduced coil power consumption, allowing for smaller coils. Even the design of the coil wound around the bobbin in a cylindrical shape has taken on new shapes such as a flat coil in force-guided safety relays, allowing for a more compact overall relay structure.

Sensitive coils allow for a more efficient operation with less power consumption by adding more turns of wire and employing thinner wire to increase the number of turns in the same space. This creates smaller, more efficient devices that can operate reliably in compact spaces while maintaining the necessary switching capabilities.

Signal relays now come in compact surface mount packages with improved materials reducing contact resistance and coil power consumption. Innovations in coil winding such as flat coils in force-guided safety relays contribute to smaller yet more powerful designs.

John Merrill comments, *"Automation in relay manufacturing has enabled miniaturisation. Using PCB-based Surface Mount Device (SMD) components for diodes and LEDs integrates extra functions within the same footprint."*

Applications in energy storage and power distribution

Relay and contactor technology is crucial for energy storage and high-voltage power distribution. *“We're typically working with 1500V DC systems and several hundreds of amps of operational current"* Ramji notes. *"With low-impedance batteries, a short circuit can generate incredibly high current surges.”*

Modern contactors handle higher voltages with improved materials, insulation and real-time monitoring. Features like auxiliary contacts provide immediate feedback on the contactor’s state, improving safety. Smart grid integration ensures dynamic load distribution, crucial for renewable energy and EV charging infrastructure.

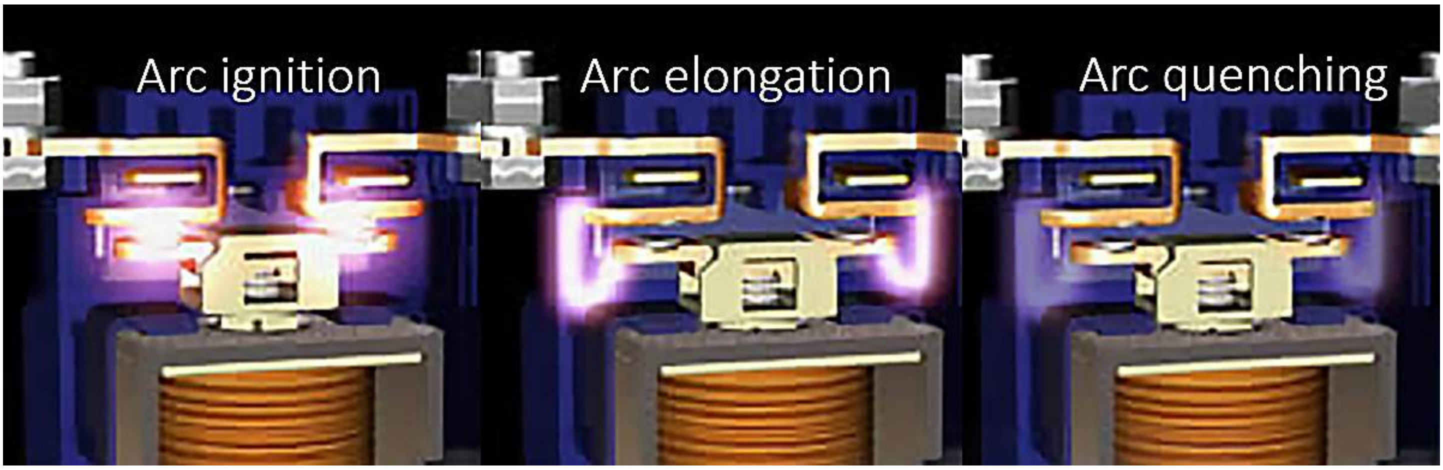
Electric vehicle and industrial applications

Ricardo Esquinazi outlines key applications: *"Today's contactors are widely used in EVs, trucks, industrial vehicles, ships, planes, energy storage systems and photovoltaic installations."* EV technology has shifted from lead-acid to lithium-based batteries, increasing voltage levels from 400VDC to 1200VDC. Fast-charging DC systems require contactors that safely manage high-voltage disconnection. Industrial vehicles such as forklifts now operate at higher voltages, increasing the risk of arcing and requiring robust relay solutions.

In EV charging, AC relays disconnect vehicles from power supplies in home and public charging stations, ensuring safety. DC fast chargers demand high-voltage contactors to handle rapid charging. Compact PCB-mounted relays are ideal for AC applications, while the CHV series HVDC contactors offer reliable high-voltage DC switching. As charging systems evolve, advanced relay and contactor solutions improve safety and efficiency in modern EV infrastructure.

System integration and maintenance

Proper system design, installation and maintenance are critical for relay and contactor reliability. Esquinazi emphasises: *"Maximum contactor short-circuit withstand must be paired with high-speed fuses—this is mandatory."*



HVDC contactors present unique challenges due to persistent DC arcs. Solutions include wider contact gaps, durable materials, dual-contact designs and arc-suppressing gas chambers. Proper magnet placement ensures effective arc deflection, while overheating risks are managed through optimised thermal design.

Predictive maintenance now relies on smart diagnostics rather than fixed schedules. Esquinazi notes, *"HVDC contactors don't need extensive maintenance - visual inspection and verifying terminal torque are sufficient. When contact resistance exceeds specifications, it indicates end of life."*

Using correct torque values is essential for reliable electrical connections. Under-tightening causes overheating and arcing, while over-tightening damages terminals and increases resistance. Regular inspections ensure system efficiency and longevity, especially in high-vibration environments like EVs.

Environmental and safety considerations

Environmental conditions impact relay and contactor performance. Voltage limits are crucial for mobile applications, with high-voltage EVs requiring specialised training for maintenance engineers. Waldis emphasises temperature control: *"Solenoids must operate within manufacturer-specified temperature limits to avoid insulation degradation, mechanical stress and corrosion."*

Esquinazi adds: *"HVDC contactors generate heat at high currents, requiring effective dissipation through conductors."* High-performance EVs, driven aggressively, experience frequent peak current surges, leading to contactor wear. Without adequate cooling, contacts may weld shut causing operational failure.

Force-guided relays enhance safety across industries by preventing hazardous failures. Their redundant contact design ensures fault detection, making them ideal for emergency stop systems, automation and robotics. Ramji underscores the importance of safe solutions: *"Without safety, everything else falls apart. Modern systems incorporate advanced arc flash prevention and monitoring to ensure operational reliability."*

Chapter 3:
Reimagining relays & contactors in tomorrow's world

As industries move toward electrification, automation and digitalisation, relays and contactors - once static components - are evolving. Traditionally essential for power distribution, switching and circuit protection, these devices are now benefiting from advancements in materials, smart technology and manufacturing processes, enabling more efficient and intelligent switching solutions.

The drive towards higher voltages and electrification

Higher voltage systems are becoming increasingly important, particularly in industrial vehicle applications. High-voltage DC relays have progressed from 12V to 48V, with some reaching 72V and future designs are targeting 1500V and beyond. Ramji explains: *"Higher voltages allow for smaller conductor sizes while maintaining power levels. However, designing 2000V relays remains cost-prohibitive due to material and component limitations."*

One significant technical barrier is maintaining isolation and insulation at these voltages. Merrill notes: *"Creepage - where an electrical arc travels along the surface - requires increasing physical distances between conductive points. While ridges and barriers help, they also increase the overall size of contactors."* New materials are being explored to resist arc tracking without increasing bulk, particularly in mobile applications where space and weight are concerns.

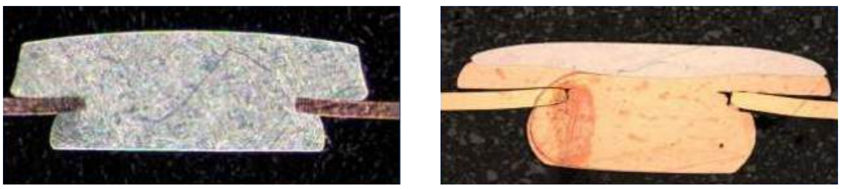
Advanced control strategies for electrification

Electrification is also reshaping solenoid design. Instead of simply increasing voltage, engineers are optimising solenoid performance through advanced control methods.

A key innovation is peak-and-hold control, where an initial high voltage ensures rapid actuation ("peak" phase), followed by a lower voltage to maintain position ("hold" phase). This approach reduces power consumption, minimises heat generation and extends operational life. As higher voltages improve efficiency, true innovation lies in balancing electrical optimisation with intelligent power management.

Innovation in materials and design

Material science plays a crucial role in advancing relay and contactor technology. Esquinazi explains: *"New silver alloys reduce contact resistance, while tungsten improves resistance to welding. Ceramic materials offer high electrical resistance, thermal stability and durability."*



Good quality rivet versus poor quality rivet

These advancements allow relays to withstand extreme electrical stresses while maintaining conductivity. High-voltage contactors, operating at 1500V or more, need to resist arc erosion while maintaining efficiency. Silver alloys reinforced with tungsten improve wear resistance, while ceramics and high-performance polymers provide superior insulation and heat resistance without increasing weight or cost.

Durakool DG19 fully automated line

Manufacturing efficiency is also a focus. While advanced materials improve electrical performance, they must be scalable for mass production. Innovations such as composite coatings, additive manufacturing and nanostructured materials are helping to create more efficient and durable relays without significantly increasing costs. Ramji emphasises: *"Advancements must enhance performance without making the form factor larger or the cost prohibitive."*

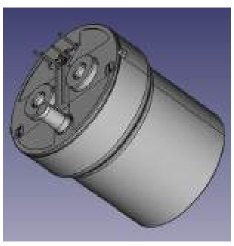
Manufacturing evolution and automation

Relay and contactor designs have remained largely unchanged for decades, but manufacturing processes have driven efficiency improvements. Merrill notes: *"Most small PCB-mounting automotive relays are produced on fully automated lines. Plug-in relay designs, however, are older and not suited for full automation."*

Automation is enhancing scalability and flexibility. A modular sub-assembly approach allows production to switch between different relay versions efficiently. By duplicating bottleneck stations, manufacturers can scale capacity without disrupting entire production lines. This ensures evolving market demands can be met while maintaining cost efficiency.

Smart technology integration

Digital advancements are transforming relays and contactors into intelligent, connected devices. Merrill predicts: *"CANBUS-enabled relays are rare now, but as they evolve, they will transition from simple relays into full CANBUS modules."*



The trend towards plug-and-play modular systems is growing, particularly in high-voltage applications. PCB-mounted contactors are becoming increasingly common in EV power electronics and energy storage solutions, offering benefits like cost savings, streamlined assembly and reduced reliance on bulky busbars.

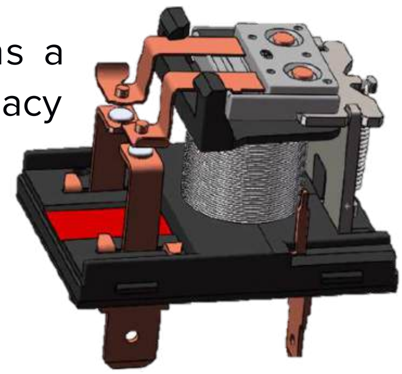
However, challenges remain. Thermal management and insulation are significant concerns as systems push beyond 1500VDC. While heavy copper PCBs improve power-handling capabilities, traditional busbars still outperform them in certain high-power applications. Despite these hurdles, manufacturers continue to integrate smart technology to enhance safety and efficiency. Esquinazi highlights: *"New HVDC contactors incorporate sensors for circuit monitoring, fault protection, overcurrent detection, temperature tracking and advanced diagnostics."*

Digital evolution and cybersecurity challenges

As relays and contactors become IoT-enabled, cybersecurity concerns arise. Connected devices provide enhanced monitoring and control but also introduce vulnerabilities. Without robust encryption and authentication, cyberattacks could disrupt industrial processes, compromise data or manipulate relay operations.

To mitigate these risks, manufacturers must implement secure firmware updates, access controls and real-time threat detection. Compliance with cybersecurity standards such as IEC 62443 ensures that IoT-enabled relays remain secure.

Beyond security, seamless system integration remains a challenge. IoT-enabled relays must communicate with legacy industrial control systems using diverse protocols such as MQTT, Modbus or OPC UA. Efficient data management and scalable analytics solutions will be key to handling increased information flow from smart relays.



DE20 with advanced features

The convergence of automation, digitalisation and smart design

The future of relay and contactor technology will be defined by the convergence of automation, digitalisation and material innovation. As industries move towards higher voltage systems, manufacturers must integrate intelligent control, advanced materials and automation while keeping costs and scalability in check.

Leveraging automated manufacturing, adopting PCB-mounted designs and integrating IoT features will enhance performance, reduce costs and improve flexibility. However, addressing challenges in thermal management, insulation, cybersecurity and integration is essential to ensuring long-term success.

Safety and efficiency as guiding principles

Amid these advancements, safety remains paramount. Manufacturers are developing solutions such as double-coil economisers, new contact materials, hermetically sealed chambers with gas mixtures and powerful magnets to enhance reliability and efficiency.

Esquinazi predicts: *"Advancements in control systems and automation will reshape future HVDC contactors, leading to smarter, more efficient and versatile devices."*

Uncertainty in future relay requirements

Predicting future relay needs is challenging due to evolving technologies and industry demands. Solid-state switching, AI-driven automation, and next-generation materials continuously reshape electrical systems. As industries advance, relay designs will need to adapt to new voltage requirements, switching speeds, and durability needs.

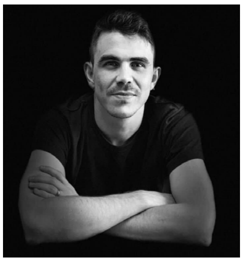
Industry-specific needs vary - EVs require high-current switching, while medical devices demand ultra-reliable fail-safe solutions. Material innovations, such as advanced composites and ceramics, could further refine relay performance. Regulatory changes will also influence relay design, mandating improvements in safety, fault detection and efficiency.

The transition to solid-state and hybrid switching technologies will impact the relay market. While SSRs offer faster switching and longer lifespans, electromechanical relays remain necessary for high-power applications.

With ongoing advancements in technology, regulation and industry demands, the specific relay requirements of the future remain uncertain. However, continued innovation, adaptability and material science will be key in meeting the needs of emerging power systems and automation technologies.

Final thoughts

Authored by Carlos Mendes, Product Manager for Switching at Durakool



As we stand on the verge of a new era in electrical engineering, the evolution of relay and contactor technology continues to develop, driven by the increasing demands of modern power systems and emerging applications. Despite the cynics of the past proclaiming the downfall of relays with the emergence of new technologies such as the transistor, the relay remains a crucial component and for good reason. This whitepaper has taken us on a journey from the humble beginnings of these essential components to their cutting-edge present and their exciting future.

The relay and contactor industry is far from static. It is dynamic, driven by the relentless march of progress. From the textile mills of the Industrial Revolution to the sleek electric vehicles of today, these unassuming devices have silently underpinned our technological advancement. They have adapted, evolved and sometimes revolutionised themselves to meet the ever-changing demands of our electrified world.

As we look to the horizon, we see a landscape rich with possibility. The convergence of IoT, advanced materials science and artificial intelligence promises to transform relays and contactors from mere switches into intelligent, predictive and self-optimising components of our electrical systems. The challenges are formidable - from cybersecurity concerns to the push for ever-higher voltages – but so is the ingenuity of the engineers and innovators driving this field forward.

Yet, amidst this whirlwind of change, some things remain constant. Safety, reliability and efficiency continue to remain at the core, guiding development. The fundamental principles that Joseph Henry discovered nearly two centuries ago still form the solid foundation of relay technology, even as we build ever more sophisticated devices.

The future of relay and contactor technology is not just about better switches or more efficient contactors. It's about creating a world where energy flows more freely, safely and intelligently than ever before.

As we stand on the threshold of this exciting future, one thing is clear: the humble relay, that unsung hero of our electrical age, will continue to play a pivotal role in powering our success for future generations.

GLOSSARY

- **AC** (Alternating Current) – Electrical current that periodically reverses direction, commonly used in power grids and industrial applications.
- **CAN** (Controller Area Network) **Bus** – A communication protocol used in automotive and industrial automation to enable electronic control units (ECUs) to exchange data efficiently.
- **Creepage Distance** – The shortest path along the surface of an insulator between two conductive elements, crucial for high-voltage insulation design.
- **DC** (Direct Current) – Electrical current flowing in a single direction, commonly used in battery-powered applications such as EVs and energy storage systems.
- **DC Fast Charging** (Mode 4 Charging) – A high-power charging method that delivers DC electricity directly to an EV battery, reducing charging time significantly.
- Energy Storage System (**ESS**) – A system designed to store and manage electrical energy, often involving batteries or other storage technologies.
- **Faraday's Law** – A principle of electromagnetism that explains how a changing magnetic field can induce an electric current, relevant in relay and contactor coil designs.
- **Industry 4.0** – The integration of automation, IoT, and digital technologies into manufacturing and industrial processes.
- Internet of Things (**IoT**) – A network of interconnected devices enabling real-time monitoring, automation, and data exchange.
- **MOSFET** (Metal-Oxide-Semiconductor Field-Effect Transistor) – A semiconductor component used in solid-state relays for high-speed and efficient switching.
- **PCB-Mounted Relay** – A compact relay designed for direct integration onto printed circuit boards (PCBs), used in modern industrial and automotive applications.
- **Peak-and-Hold Control** – A technique where an initial high voltage is applied to activate a solenoid or relay, followed by a lower holding voltage to maintain position with reduced power consumption.
- Solid-State Relay (**SSR**) – A relay that uses semiconductor components for switching instead of mechanical contacts, offering faster response times and longer lifespan.
- **Solenoid** – A coil that generates a magnetic field when an electric current passes through it, often used to control mechanical movements in relays.
- **Zero-Crossing Switching** – A switching method in AC circuits that activates when the voltage waveform crosses zero, reducing electrical noise and wear on the contacts.
- **MQTT** (Message Queuing Telemetry Transport) – A lightweight, publish-subscribe messaging protocol used for IoT-based relays and contactors. It enables real-time data transmission for remote monitoring and predictive maintenance in industrial automation and energy management systems.
- **Modbus** – A serial communication protocol widely used in industrial automation. It enables relays and contactors to communicate with PLCs and SCADA systems, ensuring seamless integration into industrial power management.
- **OPC UA** (Open Platform Communications Unified Architecture) – A secure and scalable industrial communication protocol used in digital relays and contactors for real-time monitoring, predictive maintenance, and integration with Industry 4.0 systems.

Thanks to our contributors:

Jürgen Steinhäuser
Head of Sales & Marketing
at **ELESTA GmbH**

Jürgen, a proven expert in technical metals and relay technology, has worked for many years in the development of technical metals and the effects of corrosive gases and aerosols on metals used in contact and connection technology. Since 2005, he has been a member of the management team at ELESTA GmbH, in Switzerland, responsible for sales and marketing, as well as standards and association work. He participates in working groups at ZVEI, DKE, DIN, VDI, and IEC.

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Director
at **Italiana Relè**

Born in Milan, Italy in 1952, Paolo completed his classical studies earning a University of Milan Degree in Philosophy. His professional career developed in a manufacturing company producing electromechanical components. He worked his way up to the highest levels within the same company, eventually acting as Managing Director for about 25 years. Recently retired, Paolo now consults part time in the very same field of industrial components.

John Merrill
Industry Expert
(Retired)

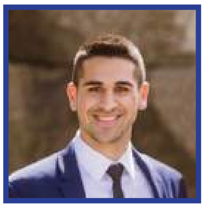
John has more than 40 years experience in the relay field. He worked as a Key Account Manager for a major relay manufacturer and as a Product Manager for Relays in distribution and latterly as Product Manager for Durakool. He specialises by solving customers problems, including by adapting, or customising, existing relays to meet customers needs. Now happily retired, and living in Lincolnshire, he still keeps a watchful eye on the relay industry and is enjoying his Ford Mustang!

John Tribe
Director
at **Foxtam Controls**

John has over 40 year's experience in industrial relay and relay logic applications, product specifying and placement, development of all relay output related products (electronic timers, control relays, sensing relays and monitoring relays), sales and marketing of the same. Foxtam Controls are a British designer and manufacturer of low voltage control and instrumentation products, established in 1977.

Ricardo Esquinazi
Brand Manager
at **Durakool**

Born in Argentina, Ricardo has lived in Spain since 2001. He Graduated in Electronic Engineering with a Master in Business administration. He has worked in relay manufacturing companies in Spain, UK, Switzerland, China and India, for more than 20 years. Ricardo commenced working with Durakool in 2017 as Business Development Manager and has since been be promoted to Brand Manager.



Alex Ramji
Director of Product Management
at **Nuvation Energy**

Alex Ramji is an accomplished electrical engineer with over eight years of experience in both the energy storage and electronic design industries. Throughout his career, he has successfully led multidisciplinary engineering teams and contributed to the development of cutting-edge technologies. As Director of Product Management, he now leverages his technical expertise and leadership experience to drive product strategy and support the continued growth of the energy storage sector.

For further information, please contact sales@durakool.com