Advantages of relay technology in rail vehicles

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Abstract

Electromechanical relay technology is sometimes regarded old and outdated. This essay shows that the use of relay technology is still very useful in railway vehicles. The simplicity of design, modification, maintenance, in combination with the safety and robustness make a well suited solution for many day to day applications.

Introduction

Reliability is a key factor in railway operation. Therefore the technology embraced by the railway industry is always 'proven' and maybe even 'old fashioned'. Still the amount of functions on a vehicle is increasing and new systems are introduced at a relatively fast pace. The shift to micro-electronics has led to decreased knowledge of, and attention to previous technologies. Also many technical scholars these days are not educated about older technologies anymore.

This essay covers the general advantages of electromechanical relays in railway vehicles and shows how to incorporate reliability and safety with relays on a simple to understand level.

Relays as interface components

Relays have some key characteristics that make them ideal components for interfacing between systems. Galvanic isolation between the coil and each of the contacts make it easy to maintain isolation between systems. Even in case of failures flash-overs between contacts or between contacts and coil are rare.

The selection of coil voltages is wide and does not limit the voltage and current ratings of the contacts. This means it is easy to select a relay that interfaces between a 12 V_{DC} control circuit and a 230 V_{AC} motor circuit for instance.

Relay coils are virtually immune to surges and EMI. With the selection of a proper surge protection element (like a fly-back diode in DC applications) the EMI from the relay coil to the rest of the system is also well controlled. In practical situations this means that your circuit will work regardless of the disturbances on the power supply line. This is a key factor in the design of safe and reliable controls.

Due to the mechanical nature and simplicity of a relay, it has predictable behavior in case of a failure. IEC 62380 shows this model in an accurate and understandable way. This allows you to anticipate a fault condition and pick the safe position of an input or output.

Relays that are equipped with a "weld-no-transfer" function can be used to sense defects in the relay that make it fail to open upon activation. When a load is controlled by NO-contacts of a relay a simple feedback of a NC-contact will indicate whether the load contacts have really closed or not. Measures can then be taken to allow the system to remain in a safe state.

Relays as control logic

With a relay being an on-off switch, it is the most basic of digital components, just like a transistor in electronics. Digital design principles like boolean operations, reduction of terms and techniques to prevent race conditions all apply to relay design. Relays can be considered, or used as logic gates.

Timer relays, latching relays and many other functions are available to simplify the design of more complex control logic. For example zero power memory functions are readily available in relay technology, providing a more dependable solution than complex PLC's with flash or EEPROM data storage.

In hybrid circuits, with both relays and programmable logic, a relay can fulfill a bypass function of safety relevant signals. For instance when introducing brake blending ([1]) a PLC can be used to translate the requested brake force to both the desired electrodynamic and pneumatic brake force values. A relay, controlled by the PLC watchdog, can then bypass the PLC during malfunction, reinstating the original link that requests the same brake values from both the electrodynamic and pneumatic brakes.

Interpretation of specifications

Reading specifications can be difficult. A line by line comparison between datasheets of different products may indicate similar properties under standard conditions, but actual performance in the field may very well be miles apart. Similarly datasheet information may indicate that a certain required value is not met under all circumstances, while field performance may exceed the specifications.

[1] Maximizing the amount of brake force from electrodynamic brakes to minimize mechanical brake wear and optimizing energy recuperation

As with many components, properties of the relay design are closely linked. For relays the minimum pull-in voltage for example is related to the ambient temperature. At lower temperatures, generally a lower voltage is required to activate the relay. One supplier may indicate minimum pull-in voltage at room temperature, while others specify at the lowest operation temperature, resulting in more reliable operation of one brand over the other.

Low and mixed contact load performance

With the introduction of digital input circuitry and low power consumption equipment (like LED's) contact loads get increasingly lower. Typically mechanical contacts have a sweet spot of operation between 20 and 100 mA at 24 to 110 V. Application of contact finishes like gold improves the low current performance significantly. Gas-filled hermetically sealed relays may also show increased performance under marginal loads, but will have negative impact on higher load and mixed load operations. Techniques that (temporarily) increase loads on a contact may bring ordinary contacts on the sweet spot of operation.

Especially in mixed load situations it is good to analyse the problem and find a solution to the problem rather than the symptom and maintain the best performance at acceptable price levels. Mixed loads are defined where two contacts within the same relay switch currents that are magnitudes apart, but also in case when one contact has large load variations over time. This may be the case when loads are controlled by several contacts or by external control.

Contact preservation by layers of inert materials (particularly gold), or the use of bifurcated contacts are good solutions to the mixed load problem. Gold plated contacts provide defence against corrosion on low load contacts, while the silver contact underneath will provide equally good performance on higher loads. Bifurcated contacts have similar properties, where the higher current density per contact, and the fact that the number of contact points is doubled, provides better low load performance while remaining the ability to reliably switch higher loads. The use of relays that combine gold plated contacts with $AgSnO_2$ (silver tin oxide) contacts are a solution when the best performance is required for each of the contacts.

Industrial relays versus railway relays

Many relays are designed for industrial operation and claim high performance ratings. Circumstances in railway vehicles differ greatly from typical industrial applications, though. Extreme vibration, frequent and wide temperature cycles and oily, corrosive and damp environments all stress components, including relays. This may result in disappointing performance when industrial relays are used in vehicles.

A good relay for railway operation has measures against the environmental influences and is certified to relevant railway standards, including EN 50155, IEC 60571 and IEC 60077. And even within the standards are levels of operation and testing that should be taken into account – not only for relays, but for any electric railway product. Specified operating temperatures, voltage swings, levels of shock and vibration are all relevant and to be considered when selecting relays.

Railway operations require fast repair times and high reliability. A well produced relay in a plug-in housing with features that allow mechanics to identify failed components (for example a transparent casing) will save tremendously on life cycle costs (LCC). And since obsolescence becomes an increasingly important factor, a long term (20 years plus) availability warrant is generally required.

Price considerations

All the aforementioned aspects come at a price. The industry is getting more price driven every day and economic considerations should always be taken into account.

On one hand relay designs are cheaper than PLC designs for simpler functions. Writing, testing, validation and certification of software is expensive, sometimes even more than the hardware. When the amount of I/O and functions are limited, the business case for relays will most likely be better.

When selecting components for the relay design however, the cheaper parts may be appealing to reduce budget impact. The costs during operation from fault repairs and end of life replacements however shall not be neglected.

"The bitterness of poor quality remains long after the sweetness of low price is forgotten" (Benjamin Franklin)

Conclusion

Relays in many cases offer reliable solutions in railway application that are easy to design and maintain and offer low costs of operation. The specification of component characteristics is however critical (as is any component selection) to reach the goal of acceptable life cycle costs (LCC) while maintaining high availability of the railway vehicle. Relays are more forgiving than semiconductors when it comes to high loads and provide very predictable failure modes, in the unlikely event of a component failure.

About the author

Mr. René Knuvers (1974) is educated in electric and electronic engineering (BSc degree) and works in railway vehicle design since 1997. In various positions with NS (Dutch state-owned rail operator) and LUCROS Railway Engineering he was responsible for the design, maintenance and modification of electric and electronic systems ranging from doorcontrol to climate systems and automatic train protection to passenger alarm systems. Landmark projects have been the integration of ETCS, ATB, PZB, SHP, KVB and Crocodile for multiple cross border locomotive types on the European continent. Many of these projects utilize relays to the full satisfaction of the customer.

LUCROS Railway Engineering is a Dutch engineering company with a sole focus on engineering for railway applications. Experienced LUCROS engineers make reliable and safe designs for rail vehicles every day. All types of technology and integration levels are covered, from ground up electrical system design, to integration of highly complex electronic systems.