Reliable relay technology in rail vehicles

Document ID: LU-4190010
Wednesday 24 July 2019

Abstract

Reliability is very important in railway technology as it is a prerequisite for safety and availability. Selecting the right components, and prediction of failures before any disruption of service occurs is vital to the industry.

Introduction

Keeping railway vehicles safe and vehicle availability high is among the most important tasks for the technical caretakers of rolling stock. Design engineers, asset managers and maintenance mechanics alike always focus on these aspects. The origin of both is the reliability of the system and its components. A component failure is often the trigger for a chain of events that eventually may lead to either an unsafe state of the vehicle, or unavailability of (part of) the vehicle.

In this whitepaper we address reliability of designs and ways to keep it at a constant, high level during the life cycle of the vehicle.

Selection of the right component

At the heart of any system are its components. Each component is to provide a particular function and the performance of the system relies on the performance of any of the components within.

Selecting the right component for the task is the first step in reaching the goal of a reliable design that is both safe and highly available. EN 50126 on RAMS (Reliability, Availability, Maintainability, Safety) specifies such a procedure in depth.

More than the expected average failure rate for a component (often indicated as the MTBF) the progression of the failure rate in a particular application is relevant to the availability and safety of a system over time. A new component may have an excellent failure rate but may deteriorate rapidly. Having a set of Weibull parameters helps grasping the theoretical degradation of the system over time but is stil a mathematical approximation of the real life performance. Actual performance may differ from one vehicle to another. The statistical values predict what will happen on average over your fleet. Actual research and monitoring show what happens in an actual asset.

Real life deviations from the statistical model occur when components encounter non-average circumstances. A vehicle is parked for a prolonged period without heating or cooling, or a mere fault in one component stresses other components over their foreseen average. All these circumstances greatly influence the actual reliability and thus life expectance of a component.

During the selection of a component these temporary overstress situations should always be kept in mind. And also the detection of above-average deterioration is an aspect that has to be taken into account.

Relays deliver predictable reliability in unpredictable conditions

In particular semiconductors have poor qualities when it comes to both loss of performance at extreme operating conditions and detectability of such stresses that may have caused harm. Mechanical components like relays are more predictable in this area and also pretty forgiving when it comes to overstress situations. To some extend mechanical contacts may even restore themselves to a near-new when operated at the right conditions. For example thin oxide-layers are easily broken down by the combination of wiping contacts and a decent contact current and voltage.

Guarding the status of a component

On a system level diagnostics are common nowadays. Automated diagnostics on a component level is however rare. For engines the number of starts and running hours is often logged to predict maintenance activities, but for control components such an indicator is often absent. Still the state of a control component can often be estimated pretty well by logging and analysing parameters regarding number of activations, component temperature and load conditions.

Modern relays for example can be equiped with modules that measure such parameters and log them over an easy to use bus to a centralized diagnostic computer. This yields many possibilities for practical use. Not only the status of the relay itself can be derived from the data, but also from the status of parts that are controlling the relays, or are controlled by the relay.

For example take a pneumatic door control system. One relay is used to control the ‘OPEN’ circuit. A second relay controls the ‘CLOSE’ circuit. By simply addressing the data of both relays the amount of open/close cycles can be determined. A motor failure or a mechanical misalignment will yield in higher currents, eventually leading to higher relay temperatures. Such deviations are detectable over time and the anomalies can be spotted before they cause disruption of commercial service.

But even without constant monitoring parameters of the components some insight in the status of a particular system can be gained during periodic maintenance. Structural testing of components for key parameters – like contact resistance that causes voltage drop, switch time and basic functionality – helps predicting the moment of failure. A go/no go test will tell the mechanic if a particular component has to be exchanged or not. On the asset management level the replacement of one particular component on several vehicles may be an indicator that a design improvement is required or at least that actual values are deviating from the predicted line.

Easy to use test devices may give little insight in the failure mode that has led to the rejection of a component. Detailed root cause analysis may at some point be relevant. Traceability of all individual components up to the level of relays and such is important to draw correct conclusions from the findings. When the usage history can be tracked, the strain that was put on a specific component is much better known and better predictions can be made for similar components in other situations.

A component should also be designed with some form of inspection in mind. Enclosed or resin encapsulated components are harder to inspect than components that have removable casings or even have transparent housings. This allows for simple and non-destructive inspection, which greatly increases chances of finding the root cause.

How it all adds up

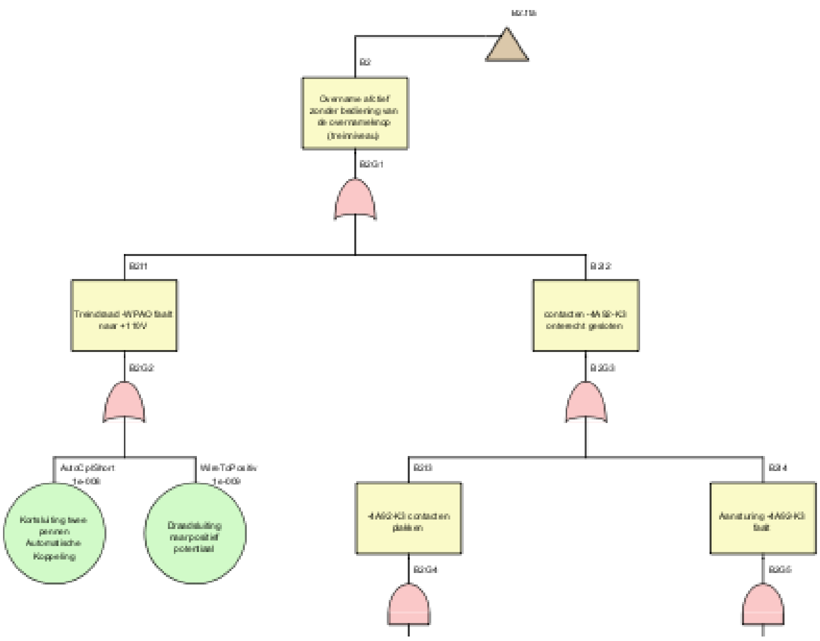

Figure 1: Part of a fault tree analysis

The contribution of a single component to the reliability of a system is determined by an often complex set of dependencies. These are mathematically described in the fault trees of the system, or sometimes in its reliability block diagrams. A single failure almost always triggers chains of events that in the end lead to some sort of unwanted behaviour. Fault rates mathematically add up in most systems. With redundancy a single failure can be contained in its impact on the overall performance of the system, but this is often expensive and effectively leads to a higher number of failures over time for individual components. Moreover care must be taken to detect the defective components before the redundant component itself breaks down.

Let's get to a real life, but hypothetical example: an HVAC system. Two months prior to an overhaul one of the fans lost a connection on the 3-phase power supply. This defect lead to higher currents in the two remaining phases and a lower level of air flow in the conduits. The HVAC control increased the airflow by increasing the control value of the variable frequency drives. This in turn increased the current through the existing phases of the fan motor even more. During overhaul the fault is quickly detected and the connection is reinstated. But during two months both the variable frequency drive and the motor (and possibly intermediate control and monitoring relays and switches) have been overstressed. Thermal deterioration of the components may lead to more severe issues later or significant reduction of the expected rest life. Overall system performance suffers greatly from these kind of events. Having more thorough inspection methods in place reduces chances of unexpected failures in the field. Being able to measure both a components state and stresses coming from its external interfaces is key to detect possible consequential damage.

In an earlier whitepaper we discussed the topic of using electromechanical relays as interface components. This places them in a position where they are both crucial to the reliability of the system, and on the sweet spot for monitoring internal and external system interfaces. In terms of reliability electromechanical relays have a well proven track record. In the Netherlands vast amounts of relays are in use daily in critical positions in safety relevant systems and comfort systems alike. The use of relays as measuring devices is just in its early stages of application as suitable relays are only coming available now. Since big data analysis is getting more and more the standard, using relays as sources for data is quite a logical step to follow.

A relay has a wide range of operation in both the control voltage and load voltages and currents. It is an ideal control and interface component that allows all ways of status checking needed for a highly reliable system.

System and design validation

A design can be theoretically verified, but the actual situation may differ quite a lot. It is good practice to test the first in class vehicle to a greater extend than routine tests. European standard EN 50155 describes such testing as type testing and it is considered a vital part of the validation process of a design.

Having plug-in relays and tools that allow for both current and voltage measurement of a relay in a design speeds up the validation process. For the standard relays used by Dutch Railways (Mors Smitt D-style relays) a shunt adapter is available that plugs in place of the relay and allows for easy access to each of the connections of both the relay and the socket. This way tools primarily intended for fault finding are also practical during the verification and validation process. Measuring actual values of voltage and current is easily done, and fault conditions or external stimuli are easily applied. Prevention of defects by unknown overstresses are the first step to really reliable designs!

Figure 2: D-Dock shunt module

Conclusion

As a chain is as weak as its weakest link, a system is as reliable as its least reliable component. Knowing the status of the components is knowing the status of the system. Being able to monitor and inspect components is the next step after monitoring the system behavior as a whole. Some components have better properties for inspection than others. Where mathematical prediction methods give an insight in the performance of a hypothetically infinitely large fleet operating at average conditions, the actual status of a single system in a single vehicle may deviate significantly. Detection of these deviations and countering its effects is key in obtaining high reliability. The selection of components is in turn extremely relevant in this matter.

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.