

Safety of Hydrail and Hybrid Trains



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White paper

Abstract

Hydrail and hybrid trains have the potential to transform the fossil-fuelled, legacy railway infrastructure and make important contributions to the reduction of harmful emissions around the globe. However, adopting hydrogen power as an energy source in railway systems introduces a number of potential safety questions. In this white paper, we'll review the safety challenges associated with hydrail and hybrid trains and discuss how overall risk assessment practices can help increase both safety and a high level of confidence in the new technology.

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Introduction

As countries around the world strive to reduce carbon emissions that contribute to environmental degradation, governments are giving increased attention to fossil fuel alternatives to power the public transportation infrastructure, including rail and bus systems. For more than a decade, rechargeable lithium-ion batteries have fuelled the growth of electrically powered automobiles and trucks. In the rail sector, however, hydrogen and hybrid

technology, i.e. the combination of a conventional drive technology and an alternative drive technology based on batteries or hydrogen, are rapidly becoming the preferred power technology for use in both existing and planned railway systems. At the same time, because of the potential dangers associated with the use of hydrogen, manufacturers of so-called hydrail and hybrid railway components and systems must include an overall safety assessment

Hazard identification is an essential part of a holistic safety assessment.

in their development process to identify potential hazards and take appropriate measures.

What are hydrail and hybrid railway components and systems?

Hydrail is a neologism, representing the combination of the words “hydrogen” and “railway.” The term is used in conjunction with any new railway equipment or system utilising hydrogen for the storage or generation of electrical or mechanical energy for propulsion and auxiliaries. This includes equipment such as pressure vessels, fuel cells and hydrogen combustion engines, and may also include rechargeable lithium-ion batteries for buffering the electrical energy that is generated.

A hybrid railway system is any kind of modern railway vehicle with a conventional power supply, e.g., with a pantograph or diesel generator, that makes use of an energy storage

system for bi-modal operation on electrified and non-electrified tracks. This electrical energy storage consists of either rechargeable lithium-ion batteries or ultracaps.

The recuperation and storage of braking energy for both hydrail and hybrid trains is an important aspect of optimising the range.



What are the advantages of hydrail and hybrid railway components and systems?

Hydrail and hybrid railway components and systems offer several important advantages over those powered by either electricity or diesel fuels. Pure electric hybrid vehicles are highly efficient and can eliminate the need for additional refilling infrastructure if their batteries can be recharged on existing electrified tracks. However, total travel distance is dependent upon the number of installed batteries, which can be comparably low due to space and weight constraints.

The hydrogen fuel cell converts chemical reaction energy into electrical current without combustion. In the process, hydrogen ions migrate from the anode through an electrolyte membrane to the cathode, where they react with atmospheric oxygen. As a result, hydrogen fuel cells produce power with no measurable emissions of carbon or any substances other than water vapour, resulting in a zero-emission, zero-carbon fuel, provided

that the hydrogen was produced in a climate-neutral way. In addition, the hydrogen stored in pressurised tanks (currently up to 35 MPa at 15°C) to power the fuel cells offers a higher specific energy density relative to the total mass than lithium-ion batteries, making it ideal for traveling long distances.

An alternative to hydrogen fuel cells is a hydrogen combustion engine. Hydrogen combustion engines produce mechanical energy that is used for traction or can be used to generate electrical energy similar to that produced by conventional diesel power packs. These engines are existing diesel engines that have been converted into hydrogen engines, thereby eliminating all emissions in accordance with EU standards. While fuel cells require highly purified hydrogen to ensure a long operating lifetime, hydrogen combustion engines can utilise a larger range of hydrogen purities.

Another potential advantage of hydrail and hybrid systems over conventional electrically powered railway technology is the lower total cost of investment. Hydrail and hybrid systems make the installation of additional contact wires for the expansion of existing electrified railway networks almost unnecessary. These benefits also translate into fewer interruptions in train service that would be required to retrofit existing infrastructures.

The first hydrail train ran in Germany in 2018. In almost all European countries, it is now planned to replace the existing diesel-powered railway fleet with hydrail or hybrid trains in the next few years. This is the only way to avoid the share of environmentally harmful carbon emissions caused by the rail sector and to contribute to meeting the commitments under the 2016 Paris Accord on climate change.



What are the safety issues associated with hydrail and hybrid systems?

Regardless of how they are powered, rail transport equipment and systems are vital to the safe and efficient movement of passengers and freight in most parts of the world. The rail industry has been a leader in its focus on safety, with train travel second only to air travel in having the lowest incidence rate of fatalities per billion passenger kilometres. These and other statistics reflect the industry-wide belief that safety is a critical concern in the design, development and operation of trains and train equipment.

When it comes to hydrail and hybrid train equipment and systems, however, managing safety concerns becomes a much more complex proposition. Hydrogen is a highly flammable source of fuel that can lead to the formation of an explosive atmosphere when improperly stored or handled. Furthermore, due to the

high operating pressures, there is a certain burst potential. Lithium-ion batteries are also associated with various fire hazards. If these are mechanically damaged or overloaded, a thermal runaway may occur, resulting in a fire or explosion. In addition, due to the chemical components of the lithium cells, there is a high toxicological hazard potential due to the flue gases produced. Even when handled properly, poorly designed or poorly manufactured batteries can easily outgas, overheat or catch fire.

Therefore, any systems intended to store or handle these alternative fuel sources must be designed to address the specific risks associated with their use. For example, onboard storage systems must be capable of safely holding hydrogen liquid or gas under high pressure. Further, hydrail and hybrid train equipment and systems

must not lead to an aggravation of the event resulting from possible train crashes and collisions. Safety concepts, operational leaflets as well as incident and emergency concepts must reflect the special hazards associated with these alternative fuels.

Unfortunately, industry standards addressing these safety concerns are not keeping pace with technology developments. For example, although standards exist that apply to the use of hydrogen fuel in motor vehicles and in industrial pressure systems, there are no standards at present that address specific influencing factors and operational constraints to the use of hydrogen fuel cells in railway vehicles. Existing European and international regulations, such as the Technical Specification for Interoperability (TSI), are currently not geared towards alternative drive systems.

Why is a risk assessment important?

In this context, the development of safe hydrail and hybrid railway equipment and systems require manufacturers and developers to adopt a robust risk management process to fully consider all specific risks associated with the use of these alternative fuel sources. A thorough risk analysis process should consist of the following four steps:

- **Risk identification** – Risk or hazard identification involves a

comprehensive evaluation of a system with the goal of identifying all deviations that could pose a potential risk under anticipated use conditions.

- **Risk assessment** – Risk assessment is the process of evaluating each technical risk that has been identified for: 1) the likelihood of its occurrence; and 2) the potential outcome in the event of an occurrence.

- **Assign level of priority** – Based on the results of the risk assessment,

individual risks should be prioritised so that risk handling efforts achieve the optimal levels of safety under anticipated use conditions.

- **Risk handling** – Finally, handling the risks involves making design changes or implementing additional safeguards to eliminate the risk or to reduce the potential safety impact to an acceptable level.

The ultimate goal of such a risk analysis is to identify the technical risks and reduce the probability of occurrence to an acceptable level through targeted measures, as well as to enable their disclosure and targeted action to limit damage.

The lack of recognised rules for this new technology currently requires a comprehensive risk-based safety verification. In order to standardise the verification procedure for hydrail and hybrid trains, to make the development process more efficient and to meet the increasing demand

for hydrail and hybrid trains, the development of a railway-specific set of rules is essential. In the medium to long term, this will make it possible to switch from a purely risk-based to a more rule-based approach to safety verification.

Working with TÜV SÜD

For more than 50 years, TÜV SÜD Rail has supported rail manufacturers, operators and authorities with a comprehensive portfolio of inspection, testing, certification and training services to ensure safe and secure as well as reliable and efficient railway transportation. With specific competencies in conventional, high-speed metro and light rail, we have worked on global rail products and collaborated with railway authorities and stakeholders worldwide. And we are globally accredited and recognised as inspection body, testing body, certification body as well as Notified Body (NoBo), Designated Body (DeBo) and Assessment Body (AsBo).

We test hydrail and hybrid trains as well as their components and systems during development and carry out an independent safety assessment according to the life cycles and requirements of EN 50126-1. This includes, among other things, the moderation and evaluation of risk analyses, review and confirmation of verification plans, testing and certification of components and assemblies, review of test specifications, accompaniment of type testing and preparation of a safety assessment report. In addition to these services, we also offer training courses on the safety of hydrogen systems and lithium-ion batteries for rail vehicles.

Our work on the safety assessment of hydrail and hybrid trains is supported by TÜV SÜD Industry Service for hydrogen component and system testing and TÜV SÜD Battery Testing for lithium-ion batteries. This allows TÜV SÜD to serve as a single source for the assessment and testing of railway equipment and systems utilising alternative fuel systems, thereby directly supporting the deployment of advanced drive technologies that are also good for the environment.

Summary

This paper highlighted that a formal risk assessment process is of critical importance in identifying potential safety risks in the design, deployment and operation of hydrail and hybrid railway equipment and systems. A thorough risk analysis

of risk can help manufacturers to speed up the development process by allowing for the resolution of safety concerns early on, thereby reducing the likelihood of last-minute design changes and delays. By working with a neutral third-party service provider,

an effective risk assessment can be conducted to support you in achieving compliance with applicable testing and verification requirements imposed by regulatory authorities.

GLOSSARY OF ACRONYMS

- AsBo – Assessment Body
- NoBo – Notified Body
- DeBo – Designated Body

FOOTNOTES

[1] Data from the European Railway Agency regarding fatalities in EU countries for the period from 2008-2010, as posted on the webpage "Railway Safety: Safety Statistics" of the International Railway Safety Council, October 2019. Available at <https://international-railway-safety-council.com/safety-statistics/>

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