



# Electrical power conversion solutions for demanding rail applications

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## Executive summary

**The rail environment has always placed harsh mechanical, electrical and environmental demands on the electrical and electronic equipment that it uses. Over recent years, these demands have been exacerbated by competitive pressures; more equipment with more functionality is being installed into limited spaces to meet higher expectations for passenger comfort and safety. Under these circumstances, simply having correctly-certified products, though essential, is often not enough. Rail product suppliers must increasingly have the ability to customise or even re-design their products to be sure of meeting individual rail project requirements – and their customers must have confidence in their ability to do so.**

## Introduction

In this article Bendi Oueini and Guy Gallet of Eaton discuss modern rail power conversion requirements and demonstrate how they are being met with a combination of standard products and innovative design solutions.

Railway systems need an ever-increasing density of electrical equipment, both on board trains and in trackside installations, to assure passenger comfort and safety, improve performance and remain competitive in different regions around the globe. However all installed equipment must deliver this functionality while operating in circumstances that are severely challenging in electrical, mechanical and environmental terms.

Many of these challenges are well-understood and universal; equipment in a rail car, for example, is always going to be subject to mechanical shock and vibration throughout its working life. Equally, though, designers and installers can be presented with difficulties arising from their particular project. For some projects, achieving the required functionality using just standard products may be impossible simply due to severe space limitations in the target installation area. In other cases, the ability to provide a compact, cost-effective solution may be compromised by all the variants essential to ensure international acceptability and standards compliance.

Even after these issues have been overcome and the equipment is fulfilling its intended role, there are further factors

contributing to its ultimate success. Its value to its owners and users is heavily influenced by its availability – the percentage of its installation life for which it is 'healthy' and able to perform its required functions. Plus, availability depends not only on reliability and therefore mean time between failures (MTBF) but also on the time taken to effect a repair (mean time to repair or MTTR) if a fault does occur. MTTR refers to the entire period between when an item fails and when it is back on line. If ways can be found to reduce diagnostics times and MTTR, the equipment's availability and value will improve.

Below we look at some examples and how they have been resolved. From this review it will become apparent that although having access to good quality, correctly-certified products is essential, it is rarely sufficient. Real success ultimately depends on having the resources and know-how to customise, enhance or if appropriate completely redesign the standard products to meet the form, fit and function required by the target project. Not all product suppliers can offer this, especially as the exercise must include qualification and production as well as design.

## Reducing EMC disturbance – without increasing rack space

EMC is always an important issue for rail equipment; the rail industry imposes its own specific EMC standards, that differ from those prevailing in other markets. In Europe, the reference standards are EN 50121-1, 2 and 3 (and -4 and -5),



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which are part of EN 50121 (Railway applications - Electromagnetic compatibility).

In a recent project for a major railway equipment OEM, there was a requirement for a large number of DC-DC converters. Although the requirement was nominally for a single power supply, paralleling was used to reach the required power output, and to build in redundancy for safety reasons. This meant that twelve DC-DC converters were required. The system configuration comprised four racks, each 6U high and containing three converters together supplying 140 W. In the original customer configuration, the racks also contained a large number of EMC input filters to ensure EMC standards compliance. The total cost became extremely high and the solution was difficult to integrate. Figure 1 shows the configuration.

Nevertheless the initial implementation was acceptable to the French market because only the OEM used the 24 V input. The requirement was limited to ensuring that the system itself was functional. However, once the OEM addressed a wider export market in Northern Europe, other equipment needed connection to the 24 V supply, with protection from EMC disturbance. Accordingly the OEM asked Eaton to solve this issue.

Achieving this level of compliance for 12 converters in parallel was a big challenge, as it was not possible to free up extra rack space, change the cabling or increase converter size. Eaton's response was to spend some weeks working on the converter printed circuit board CAD layout and component placement, while also making strategic frequency adjustments. This has allowed a solution to be finalised in which the complete cabinet has successfully passed the required level of EMC compliance.

After completing many steps to validate the solution, EMC noise has been reduced by a factor of 2 or 3; no disturbance is experienced by systems sharing the 24 V supply. The original converter and cabinet dimensions have been preserved, and the solution is also very cost-effective.

### A single wide input voltage range solution

Many different battery voltages are in use within the rail industry. Variations depend both on the geographical location and the application. In France for example, differing voltages are in use even in different parts of the country.

Standard EN 50155 defines the set of allowable battery voltages; 24 V, 36 V, 48 V, 72 V, 96 V and 110 V. The minimum and maximum cell tensions are between 0.6 V Un and 1.4 V Un. For applications, the voltages are usually grouped into three ranges; 24 – 36 V, 48 V and 72 – 110 V. This leads to a proliferation in equipment variants, as three different equipment versions are needed for the three voltage ranges as defined. Development costs are therefore multiplied by three, as are the costs for thermal, EMC and vibration qualification testing. Stockholding requirements are also multiplied by the same factor.

When a large systems customer came to them with a requirement for four or five DC-DC converter variants with different input voltage ranges, Eaton proposed an improved, more

cost-effective solution; a universal wide-input unit with a voltage input range of 16.8 V to 137.5 V to eliminate unnecessary equipment proliferation.

This yielded a number of advantages. The increase in material cost was less than 10%, which was more than offset by savings in testing requirements. Avoiding a change in input voltage range eliminates the related possibility that a product's EMC performance may change, so no new EMC test is needed. Triplicate thermal and vibration qualifications are also avoided. The reduction in testing saves time as well as cost, so the customer received their products more quickly as a result of the single solution. The customer's own qualification testing burden was similarly reduced, adding to the cost and time savings. Further cost and time savings accrued from the reduction in stock requirement and logistics management.

### Diagnostic communications reduce equipment and train downtimes

As little as five years ago, a piece of equipment such as a DC-DC converter was considered acceptable for rail applications if it was suitably certified and functional. With today's pressure for improved productivity and reliability, this is no longer necessarily the case – and nor does it have to be. Electrical and electronic equipment can have built-in diagnostics and communications capability, so that the cause of a failure can be identified very soon after it occurs.

Without such capability, fault diagnosis in a complex application such as a train is very difficult and time-consuming – especially if the fault is intermittent, temperature-related or in some other way transient. Consequently, a fault incident and its diagnosis can take a train out of service for several hours or even days.

By contrast, adding diagnostics capability and the ability to communicate status and fault information over, say, a CAN bus can reduce diagnostics time to a couple of minutes rather than hours or days. After that, repair of a DC-DC converter is usually simple, as it can typically be effected just by exchanging the faulty plug-in converter rack module.

In addition to diagnosis of faults in real time, the information available across the CAN bus is also valuable for longer term preventative maintenance. Parameters including output voltage, internal temperature, power consumption and output power can be analysed by a failure mode and effect analysis (FMEA) tool to identify and reveal problems, allowing action to be taken before they can cause failures.

This capability has obvious advantages for significantly reducing downtime, but it has another benefit too. It allows systems providers to identify and prove when the root cause of a fault lies outside their system. The ambient temperature, for example, may have climbed to an excessive level, subjecting their equipment to out-of-specification operating conditions.

Status and potential fault data is continuously being generated by DC-DC converters as a natural part of their operation. Eaton has already successfully implemented CAN bus-based systems for trucks, and is now using this expertise on further rail system development.

Exactly which information should be extracted and transmitted, though, and how it should be presented to operators, is still a matter for discussion. Fully exploiting this data to develop the best possible information depends on a strong customer-supplier partnership; this is the only way to ensure that the best possible understanding of the converters' operating modes is added to the deepest insight into the conditions found on board a train.

### Conclusions

In this paper we have seen how problems can be solved and solutions made more efficient and cost-effective by customising or re-designing products to overcome the challenges of a particular application. To put it another way, many projects simply would not be viable at all without this special design, qualification and manufacturing effort.

Indirectly, the customer also contributes to the success of such projects. These could not be initiated unless the customer has sufficient faith in the supplier's capabilities, and belief in a successful outcome, to authorise the project from the outset. Customers find this investment of faith easier with companies like Eaton that can demonstrate thirty years' experience in transportation power supplies, as well as similar experience in other equally demanding industries.

Over this period Eaton has built up strong expertise in EN 50155 and EN 50121-2-3 requirements, together with a strong knowledge base in environmental conditions. MTBF calculations and FMEA analysis tools are backed up by extensive in-house testing equipment deployed across development and production facilities in France, the UK and Tunisia.

Eaton now has 500,000 products that range in power from 15 W to over 30 kW, installed in trains and trackside applications throughout the world. With proven reliability, they comply with all applicable rail standards. They are ruggedized to withstand a range of environmental conditions as appropriate to their applications; these include not only vibration, EMC requirements, wide temperature ranges and wide input voltage ranges, but also extended hold up times, salted fog and humidity.

If you would like to understand more about how Eaton can design, qualify and manufacture a power solution that fully complies with functional and environmental specifications, visit our website or talk to our team of applications specialists using the contact information below.

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