RSSB is a not-for-profit company supported by major rail industry stakeholders.

RSSB facilitates the resolution of difficult cross-industry issues and builds consensus.

RSSB delivers a unique mix of products and services to the industry – supplying knowledge, analysis, technical expertise, and information and risk management tools.

RSSB and the rail industry work together to:

- Continually improve the level of safety in the rail industry
- Drive out unnecessary costs
- Improve business performance

The company is limited by guarantee and is governed by its members, a board, and an advisory committee. It is independent of any single railway company and of its commercial interests.
A key part of RSSB’s product range is the research and development (R&D) programme that it manages on behalf of the railway industry. The programme is funded by the Department for Transport (DfT) and aims to assist the industry and its stakeholders in achieving key objectives:

- Improve performance in terms of health and safety, reliability, and punctuality
- Increase capacity and availability
- Reduce cost
- Integrate all of these to compete effectively with other transport modes (or complement them as appropriate)
- Delivering a sustainable future for the railway

The RSSB-managed rail industry research programme focuses on industry wide and strategic research that no individual company or sector of the industry can address on its own. The programme is also instrumental in supporting the development of a future vision that can best be delivered. In addition, RSSB manages the rail industry strategic research programme which has been specifically developed to support industry and its stakeholders in the delivery of ‘step changes’ in the industry in 10, 20 and 30 years time – as outlined in the Rail Technical Strategy.
This covers five major research topics, all concerned with reducing risk relating to the infrastructure, the rolling stock, their interaction with each other, and processes that keep the railway moving.

This booklet focuses on the Energy area of RSSB and the principal client group for this area is the Vehicle/Train Energy System Interface Committee. Its aim is to:

- Inform you about research that has been done
- Show you where to find the results of the research
- Encourage you to find out more including registering to receive the RSSB R&D e-newsletter
- Encourage you to register on RSSB’s sharing portal for access to rail knowledge (SPARK) http://www.sparkrail.org

The R&D programme has generated substantial knowledge, information and resources – all specifically designed to support the rail industry’s day-to-day operations, at senior level and on the front line.

This booklet provides only a brief insight into research projects - the best way to find out more about each project is to go to the research and development section of the RSSB website - www.rssb.co.uk - where you can find more details, including links to the research reports and outputs.

Key Contact:
Head of Engineering Research
R&D Programme
RSSB
enquirydesk@rssb.co.uk
The scope of the Energy topic covers both the European sense of the term meaning Electrification, as well as the wider meaning of the source of power for the railway such as portable energy. Research in this topic area covers: traction energy sources, electrification safety, electrification systems, fixed interface equipment, and vehicle-mounted interface equipment.

The Energy topic includes research in four areas which are:

Area 1: Research into the identification and deployment of electrification safety controls to manage the associated safety risks

Research has been carried out to investigate the effectiveness of electrical section protection and to review and develop safe working practices in electrified areas, including the application of the Physical Agents (Electromagnetic Fields) Directive on railway operations.

Cross-Industry Groups

The cross-industry group for the Energy research topic area is the Vehicle/Train Energy System Interface Committee, with some projects being delegated to sub-groups including the Future Energy Technology Group, and Future Electrification Group.
Area 2: Research into optimising electrification systems (including interfaces, performance, and costs) to provide a cost-effective electric railway

Research has been carried out to investigate the potential for improvements in electrification and propose mitigation techniques that deliver benefits in the short-term, and influence system design in the long-term. Some projects have investigated whether it would be possible to install an economic electrification system with ‘gaps’ in the electrical continuity of the traction contact system.

has also contributed to a major EC FP7 Project to look at ways of reducing the cost and time taken to achieve trans-European rail vehicle certification.

Area 3: Research into the sustainable use of energy to maintain rail’s competitive advantage

Some of this research has been completed and investigates how energy can be used more efficiently, either by re-using energy (as in the case of regenerative braking), reducing overall consumption (such as by reducing vehicle mass or metering), or seeking more efficient ways of converting source power into power at the wheel/rail interface.

Area 4: Longer term research which supports the implementation of the Rail Technical Strategy

The Rail Technical Strategy was issued on behalf of the industry in 2012. The industry is developing research portfolios in support of the strategy. The most important of these is a move towards a wholly electric railway.
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<tr>
<td><strong>Description</strong></td>
<td>This project assessed existing methods of protecting traction power supply sections, to identify improvements to the speed and selectivity of fault detection that could reduce the impact of faults on the railway.</td>
<td></td>
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<tr>
<td><strong>Abstract</strong></td>
<td>Improvements to the speed and selectivity of fault detection on traction power supply systems would limit the impact of the fault itself, thus reducing the consequential effect on the railway system. This project assessed existing methods of traction power supply protection, the associated risks and the possible options for alternative arrangements offering improved risk mitigation. The report provides an understanding of the possible methods of risk reduction associated with detection of faults on electric traction systems and inappropriate re-energisation. It provides draft information to be included within the future Railway Group Standards for the electrification/energy system and indicates areas where further detailed research may deliver benefit. The work was used in research T345 Review and development of safe working practices in electrified areas.</td>
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<tr>
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<tr>
<td><strong>Current Position</strong></td>
<td>This research project has informed the development of electrical protection schemes and traction systems and has been developed through work within Network Rail.</td>
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The outputs of the research will be used to inform the development of measures to be included within the future Railway Group Standards for the electrification/energy system. It has also been used as part of research project T345 Review and development of safe working practices in electrified areas.
# T345  Review and development of safe working practices in electrified areas

## Description

Prior to working on electrification equipment a sound and systematic approach is required to render the equipment safe. This project reviewed the current practices with the aim of improving safety and efficiency.

## Abstract

During the process of rendering electrification equipment safe to work on, there is potential for mistakes to occur and for miscommunication between parties. Also during normal operation of the railway, and particularly under fault conditions, dangerous voltages must not appear on the running rails or on other accessible metal work. This project reviewed the basis on which practices for isolation and earthing during commissioning and maintenance have evolved, and reviewed whether any changes are needed. It investigated the design of electrification equipment and its protection including the use of technology based solutions to mitigate risks. The role of modern digital communication systems was also considered. The industry will be utilising the findings of this research to develop safer working practices.

## Published

July 2007

## Current Position

This research project recorded and investigated the safety of the systems of work, and was used to inform the development of revised processes in the Network Rail documents *Working on or about 25 kV electrified lines*.

The findings of the research have also been considered in the development of new measures within the future Railway Group Standards for the electrification/energy system.
T346  Investigating the potential for improvements in electrification systems

Description
Failure of the electrification system causes severe disruption to train services. This project reviewed failure trends to propose mitigation techniques that deliver benefits in the short-term, and to influence the development of more robust systems.

Abstract
Failure of the 25 kV overhead line or third rail power supply system causes severe disruption to train services and can pose safety risks through ensuing disruption. This project aimed to identify design improvements to yield additional safety and operational benefits. The initial phase of the project reviewed recent failure trends and, in particular, established the role played by pantograph shape and contact wire position in de-wirement incidents. This work shaped a second phase that considered future requirements of the power supply system, also learning from other railway administrations and available technologies where possible. The project output will assist Great Britain’s rail industry and the suppliers in identifying opportunities to improve the operation of electrification systems, particularly at the current collection interface where any failures may cause severe disruption to train services.

Published
February 2008

Current Position
The findings and recommendations of this research are now closed as they have been considered by the Future Electrification Group and the Vehicle/Train Energy System Interface Committee and will be taken up by the relevant duty-holders as and when appropriate during future works. The findings of the research have also been used in the development of new measures within the future Railway Group Standards for the electrification / energy system.
Description
This project studied what effect the Physical Agents (EMF) Directive might have on Railway Group Members, by reviewing operational processes that may expose their staff to electromagnetic fields.

Abstract
When this project was started the European Directive 2004/40/EC on Physical Agents (Electromagnetic Fields) was scheduled to be transposed into UK regulations by April 2008. Transposition has been delayed until at least 2012 and a draft revised directive is anticipated in 2010.

The Directive 2004/40/EC promotes improvements in the health and safety of workers. It concerns the effects of exposure to electro-magnetic fields (EMF) on the human body and sets exposure limits based upon extensive research into the effects of EMF (varying from DC to 300GHz).

On behalf of Vehicle/Train Energy System Interface Committee this project looked at whether Railway Group Members have any activities in their operations that will require assessment and potentially any mitigation measures as a result of the introduction of this Directive. This research involved a workshop, computer based modelling and emission measurements. The research concluded that the railway group members would be broadly compatible with the requirements of the Directive.

RSSB will await the outcome of European Commission deliberations, and publication of the revised Directive (draft anticipated in 2010); and then seek industry guidance on the need to undertake further work to support industry compliance with the UK regulations based upon the revised Directive.

Published
November 2009

Current Position
This project (T515) investigated the application to the GB railway system of European Directive 2004/40/EC on Physical Agents (Electromagnetic Fields). This was the third Directive in the suite of physical agents’ Directives, and although published in 2004, the implementation was postponed to allow improvements to be made because of a number of technical concerns.
The findings of this report have been used to inform a response from the GB railway industry to consultation on an impact assessment commissioned from FICETTI (the Finnish Institute of Occupational Health), and to a European Commission consultation with 'social partners' who are representative bodies across Europe, including trade associations and trades unions. In the context of the railways these are the CER (The Community of European Railway and Infrastructure Companies) and the EIM (European Rail Infrastructure Managers).


RSSB and LUL representatives will monitor the transposition of the Directive into UK legislation and development of general UK guidance. In addition, the Vehicle Train Energy System Interface Committee has requested further research to be undertaken to review and update report T515 in the light of the revised Directive. A new Research and Development project (T1051 – Investigation into the effects of applying the Physical Agents (EMF) Directive in the UK railway system) is taking this forward.

This further research will enable the GB railways to engage on an informed basis with the HSE who are responsible for the transition of the Directive into UK legislation, and the ORR who will be responsible for enforcement on the railway. HSE anticipate that a significant number of the requirements of the Directive are already incorporated into UK law through the Management of Health and Safety at Work Regulations 1999, supplemented with a small amount of additional legislation.

The European Commission will publish a Practical Guide early in 2016, supporting the Directive, and HSE, working with stakeholders may provide further practical guidance to support UK implementation.
### Description
This project studied the viability of hydrogen as a fuel for the rail industry. It explored the technology, how it can be developed and whether or not there is a business case for such development.

### Abstract
Hydrogen fuel has been researched extensively in other transport sectors, particularly automotive. This project explored the issues that the technology presents to the rail industry, how it can be developed and whether or not there is a business case for such development. The work considered use of hydrogen in fuel cells as well as internal combustion engines (ICEs) finding that, whilst hydrogen ICEs are further developed and cheaper than fuel cells at the moment, they are only about half as efficient. With the present method of producing hydrogen, ICEs have a worse impact on CO₂ emissions than current diesel technology, but fuel cells show a substantial improvement. This said, hydrogen fuel cells are very unlikely to be used in mainstream rail applications until there has been an order of magnitude reduction in cost and improvement in the average operating lifetime. Commercially, hydrogen fuel technology is unlikely to become a mainstream part of the transport energy mix until at least 2020, and even then the first applications will be for road vehicles. Key stakeholders are progressing further work, which includes monitoring developments in other transport sectors and studying the long-term merits of electrification for Britain’s railways.

### Published
April 2005

### Current Position
This research led to the formation of a Future Fuels Technology Group (now known as the Future Energy Technology Group) to consider the various fuels and storage technologies that might be applied to GB’s railway over a thirty year horizon. The findings of this research project indicated that hydrogen is a conceptually viable fuel and informed research project **T722 Hydrogen fuel cell trial**.
### T536 Investigation into the use of sulphur-free diesel fuel on Britain’s railways

<table>
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<tr>
<td>Abstract</td>
<td>To help reduce harmful emissions into the environment and comply with the European Directive on Non-Road Mobile Machinery, Britain’s diesel-powered rail vehicles will need to switch to reduced sulphur diesel during the next five years. With any change of this magnitude, there is a significant risk to the reliability and performance of the diesel fleet. This could prove to be very costly for the industry if the fuel is not tested before widespread introduction. The aim of this project was to trial the use of sulphur-free diesel (SFD) in order to understand the advantages and disadvantages. The project conducted engine test bed trials on a representative sample of engines, followed by service trials on specific engines on trains in service. The results of this work have enabled the rail industry to assess the implications of the wider introduction of SFD fuel with increased confidence. The work also considered the future use of the diesel engine in rail traction over the next fifteen to thirty years, as far as this could be reasonably ascertained.</td>
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<td>Current Position</td>
<td>This research project has provided insight into understanding the problems associated with introducing a new type of diesel fuel onto the GB railway and has also informed the train operating companies’ strategic decisions regarding which new diesel fuels can be safely implemented. Further research has been undertaken in research project T697 Investigation into the use of bio-diesel fuel on Britain’s railways, which also looked at alternative diesel fuels, in particular biodiesel, for use on the GB railway.</td>
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T558 Improving the design of DC conductor rail straps

**Description**
This project has looked at options for improving the design of conductor rail straps with regard to ease of use, reliability of contact and security of application.

**Abstract**
In a review of the processes for securing the safety of staff working on D.C. lines, Her Majesty’s Railway Inspectorate (HMRI) identified fourteen improvements to the safety of trackside workers. One of these related to conductor rail straps that are used during the process of isolating conductor rail systems, with some reservations on their clamping being expressed. This project has sought commercially available improvements to the existing conductor rail straps with regard to ease of use, reliability of contact and security of application. A functional specification has been derived based on discussions with possession managers and end users, to be used in design evaluation. The current strap, a prototype alternative and a third at a conceptual design stage, were then evaluated against this specification. Of the three D.C. conductor rail straps, neither of the new designs exhibited an overall performance gain over the existing design when applied correctly.

**Published**
June 2006

**Current Position**
The research investigated both the design of the existing short circuiting strap, and a number of alternative designs. The conclusion that the present design of short circuiting strap was satisfactory when applied as designed was accepted by HMRI, and the relevant action from its review was closed. None of the alternative designs offered any commercial benefit for application.
T580  Regenerative braking on AC and DC electrified lines

**Description**

This project investigated the extent to which regenerative braking is used currently on Britain’s main line railways. It examined the scope for further use, and established the anticipated scale of energy efficiency and CO₂ emissions benefits which might be realized over future years.

**Abstract**

There is a desire to further improve the environmental performance of rail and combat rising energy costs. Regenerative braking can improve energy efficiency and lower the rail industry’s indirect emissions of carbon dioxide (CO₂). To date there has been limited use of regenerative braking on Britain’s main line railways. In April 2006 only 12% of the national electric fleet was using regenerative braking; this study was undertaken to examine the scope for increasing its use.

Whilst deployment on the AC electrified railway was found to be good, regenerative braking has not yet been taken up widely on the DC electrified railway. One of the major technical barriers to its deployment has been the challenge of introducing regenerative braking without the need for extensive and costly changes to the electrical protection systems associated with the DC conductor rail system. Examination of this barrier has revealed that a risk based approach offers the prospect of progressive implementation of regenerative braking on the DC electrification system without expensive system-wide modifications to electrical protection systems.

At present around 3,000 older vehicles are not capable of using regenerative braking. Over time these could be replaced with new vehicles capable of regeneration, providing additional annual benefits.

Therefore, further substantial annual savings of up to £10 million in energy costs and 100,000 tonnes of CO₂ are potentially available over time from the wider deployment of regenerative braking on Britain’s main line railway.

In addition the report has identified that developments within the European and GB standards arena can help ensure the benefits of regenerative braking are exploited and safeguarded in future.
Abstract

This research work has helped to support the pan-industry regenerative braking working group, as it seeks to facilitate further implementation.

Published

August 2008

Current Position

The research demonstrated the benefits of regenerative braking and is being used by the industry-wide Regenerative Braking Steering Group which is actively championing the introduction of regenerative braking. On the AC railway the majority of vehicles that can use regenerative braking are now doing so, and on the DC railway, steady progress is being made towards full implementation, which is nearing completion. Regenerative braking will not be implemented where it is not commercially or technically viable. Regenerative braking has now become the norm for all new vehicles and major upgrading of existing vehicles.
## T618 Improving rail's energy efficiency

<table>
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<th>Description</th>
<th>This project looked at the ways that the railway currently uses energy for traction and non-traction purposes to assess current efficiency and recommend improvements.</th>
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<tr>
<td>Abstract</td>
<td>Whilst rail has an established and deserved reputation as an efficient and clean form of transport, the industry has become increasingly aware of the need to use energy even more efficiently, given the associated financial and environmental implications. Consequently, the way in which Britain's rail industry consumes traction and non-traction energy has been researched with a view to identifying the potential for making savings. A number of significant opportunities for saving energy have been identified, some of which can be realised short-term. Other opportunities will take longer as they are typically more complex and may require, for example, many parties to take coordinated action, the development of emerging technology, or are related to progressive replacement of long-life high-value assets. With the measures widely implemented there is a real prospect of saving energy costs in the order of £68m pa in the next few years and reducing consequential CO\textsubscript{2} emissions by around 521,000 tonnes pa.</td>
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<tr>
<td>Published</td>
<td>April 2004</td>
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<tr>
<td>Current Position</td>
<td>This report should be considered as an aide memoire that guides the reader towards those areas where energy savings can be made. Many of the train operating companies are actively pursuing some of the potential savings that can be made. Items that are being adopted include the use of new technology such as LED lights, and optimal design of air-conditioning. Changes in operating practices include the use of shorter trains during off-peak hours, energy efficient driving styles, management of stabling and hotel loads, and reduction in diesel engine idling. It is expected that the introduction of traction metering onboard trains will further stimulate the introduction of initiatives considered in this research. Research project <strong>T839 Eco-driving: understanding the approaches, benefits and risks</strong>, was undertaken in the Operations topic of the research programme (for further details on this research see the Operational Safety research guide) in order to validate the economic savings available by eco-driving and also to investigate the safety risk implications.</td>
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</table>
**T633  Study on further electrification of Britain’s railway network**

**Description**
This project will help to inform the development of a long-term traction energy strategy for the British railway network, consistent with overall government strategy for sustainability.

**Abstract**
Electrification has potential long-term environmental sustainability benefits because it links railway usage directly to the primary energy network. It also has the potential to reduce dependence on fossil fuels through established and mature technology: in the longer-term current fuels may become limited in supply and more expensive. Electrification, however, adds to the infrastructure capital cost and changes the balance of complexity between the trains and other infrastructure and depot fixed assets. A previous study by RSSB, T531 Feasibility study into the use of hydrogen fuel, recommended that further consideration be given to the long-term economics of further electrification of the main line network. This project provides cost and economic models that Government and the rail industry can use in evaluation of electrification proposals against traction energy alternatives. Initial demonstration of the models on five sample routes confirms that electrification can potentially be justified where a route has a dense service pattern that is well used, but the high capital cost is difficult to justify elsewhere.

**Published**
July 2007

**Current Position**
This report stimulated the consideration of further electrification within GB. The High Level Output Specification (HLOS) 2012: Railways Act 2005 statement, published by the Government in July 2012, consolidated previous announcements and further extended the proposed electrification schemes. These include plans to electrify the Great Western Main Line as far Bristol and Swansea, and the Welsh Valleys; the Midland Main Line; an ‘electric spine’ route from Southampton to the Midlands; and lines around Liverpool, Manchester and Blackpool. Network Rail has also developed a Route Utilisation Strategy that considers a more substantial plan for electrification.
T697  Investigation into the use of bio-diesel fuel on Britain’s railways

<table>
<thead>
<tr>
<th>Description</th>
<th>This research project has assessed the impact of bio-diesel in the diesel engines of railway locomotives and diesel multiple units of Great Britain.</th>
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</table>
| Abstract    | Over the next decade, the rail industry has an opportunity to further improve its environmental performance by using greener fuels. The European Renewable Energy Directive requires that, by 2020, 10% of all UK transport energy comes from renewable sources. This research, on behalf of the Diesel Metering Group (DMG), a sub-group of the Vehicle/Train Energy System Interface Committee, investigated the impact of using bio-fuel in the diesel engines of locomotives and diesel multiple units. From desktop studies, test bed trials and in service trials the DMG has concluded that B20 (a 20% blend of biofuel mixed with 80% ultra-low sulphur diesel) is sensibly the highest blend that could be universally accepted without significant expenditure to retune some engines. The DMG has also concluded that there are two important barriers to bio-diesel use:  
• The first barrier is sustainability of the source fuel. This is a political/environmental decision and requires verification of the source of the fuel.  
• Secondly the research has shown that, for biodiesel blends up to B20 the concern is an economic one and not an engineering one. The Department for Transport (DfT) will soon begin a consultation on the Renewable Transport Fuel Obligation that will look to extend the current requirement for all road vehicle fuel to be supplied with 5% from renewable sources by 2010 to apply to the rail sector. This research will enable the DfT and the rail sector to consider the bio-diesel blend ratio in meeting these expectations going forward. Further, the DMG is recommending a certification scheme to government with tax rebates in order to facilitate the uptake of bio-diesel by train operators. |
| Published  | August 2010 |
From this research project the Diesel Metering Group (DMG) has concluded that there are two important barriers to bio-diesel usage. These are:

- Sustainability of the fuel source. This is a political/environmental decision and requires verification of the source of the fuel.
- For bio-diesel blends up to B20 the concern is economic and not engineering.

ATOC and key members of the DMG continue to promote the findings and results of the research to other industry members including presentations at sustainability conferences and engineering forums. The findings have been used by ATOC in support of discussions with HM Treasury; and are used by parties involved in franchise bidding, as to the trade-off between cost of operation and other government targets. The Department for Transport has started consultation on the Renewable Transport Fuel Obligation.

By the end of 2013 it was observed that advanced biodiesel can now be produced through a number of methods, for example gasification of certain feedstocks or biogenic wastes. Residues from pulp/paper can also be used to produce biodiesel. Over the last few years, scientists and engineers have also been working to develop an efficient way of using algae on an industrial scale to convert into fuel.

The rail industry is tracking the progress of this technology.
T721  Review of potential rail vehicle fuels and ‘energy carriers’

**Description**

This project considered the potential of more radical and long-term solutions for energy such as biogas, methanol, ammonia, battery technology, and flywheels.

**Abstract**

The ATOC Future Energy Technology Group (FETG) is considering improvements that can be made to fuels along the ‘mainstream’ path through gas oil, low-sulphur diesel and bio-fuel, using virtually unmodified diesel cycle internal combustion engines. This project considered the potential of more radical and long-term solutions such as biogas, methanol, ammonia, battery technology, and flywheels. Furthermore the project also considered whether these solutions could work in isolation or in conjunction as hybrids with internal combustion engines or even the Stirling engine (external combustion engines).

**Published**

May 2008

**Current Position**

This project was initiated by the FETG to establish what potential there was for the application of novel fuels in the rail industry. The report did not find any further suitable fuels that had not been previously identified, and concluded that improved diesel fuels, whether from mineral or bio sources were amongst the most suitable for rail application. Of the novel fuels only hydrogen could be considered to be a contender in the future. Other projects such as T722 Hydrogen fuel cell trials and T697 Investigation into the use of bio-diesel fuel on Britain’s railways have already considered these fuels.

Further work on the use of energy storage devices, such as the various battery technologies and flywheels, was completed in T779 Energy storage systems for railway applications.
T722 Hydrogen fuel cell trial

Description

The purpose of this research was to develop Britain’s position with respect to hydrogen-fuelled rail vehicles.

Abstract

Following the completion of research project T531 Feasibility study into the use of hydrogen fuel the Future Energy Technology Group (FETG) supported proposals for a rail fuel cell demonstration. This research was commissioned to inform long-term thinking about the use of hydrogen fuel cells, and provide the rail industry with a viable alternative to gas oil and electrification.

Feasibility studies were made for fitting a hydrogen fuel cell to a diesel HST for auxiliary power supply, and fitting a polymer electrolyte membrane fuel cell to a passenger vehicle for traction power on non-electrified branch lines. This work was done to assess the practical risks associated with doing a hydrogen fuel cell trial.

This project demonstrated that a hydrogen fuel cell trial remains a practical means of informing the rail industry of the operating implications of the technology, allowing the industry to intelligently specify future rolling stock and energy/infrastructure requirements.

A practical operating demonstration will also inform future standards and operating practice and give a definitive answer on whether hydrogen, for fuel cell motors, is a viable portable fuel. However, the costs of staging such trials are significant, and it has been agreed that now is not the right time to undertake them. In the meantime, the FETG has agreed that fuel cell technology and associated gas storage technology improvements should continue to be monitored, together with changes in funding and availability of donor rolling stock.

Published

May 2009

Current Position

The FETG was keen to participate in a European project to develop a hydrogen powered train. However the development funding priorities in Europe were focused on automotive applications and it was not practical for GB to develop a project alone.
Current Position cont.

The project is not being progressed at this stage; it was agreed that the FETG would continue to monitor developments in this area. As part of this monitoring, contact is being maintained with an American company that has constructed a hydrogen hybrid fuelled shunting locomotive.
### Description
This project was planned to evaluate the options for the replacement or development of power sources and drive trains for future diesel multiple units; with the aim of delivering efficiency and environmental improvements, taking due account of cost, performance, and legislation.

Before committing to a significant programme of work, an initial costbenefit analysis for the whole project was conducted. It established that there was insufficient justification to progress this project.

### Abstract
The present generation of diesel multiple unit fleets is approaching the end of its life and orders for replacements will need to be made by 2013 to allow delivery to start in 2014-2016 to meet the Persons of Reduced Mobility TSI accessibility requirements by 2020.

A 3-year, multi-million pound programme was proposed to establish what advances in technology the GB rail industry could harness to deliver more efficient and reliable vehicles that would reduce the impact on the environment throughout their lifecycle.

Before committing to this programme a cost-benefit analysis was conducted, underpinned by the scale of economic benefits resulting from the provision of more energy efficient and environmentally friendly DMUs in the future. This work also included a review of the initial programme cost estimates and schedule, and was supported by a number of additional studies.

The benefit/cost ratios for three profiles (500, 1000, and 2000 new DMUs) all returned poor value for money results. Key aspects in determining these results were the uncertain profile of vehicle replacements over the next 30 years; the impact of an electrification programme on DMU requirements; and current activities to evaluate options to re-engine existing DMUs. In light of this, the rail industry considered that undertaking lengthy research on possible solutions could not be justified.

### Published
May 2009

### Current Position
RSSB published a research brief summarising the results of the cost benefits analysis report, which supported the industry decision not to pursue research in this area at this time.
<table>
<thead>
<tr>
<th>T777 Understanding the effect of ‘gaps’ in electrical continuity of the traction contact system</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
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<td>This research project investigated the effect of ‘gaps’ in traction power supply systems. It has identified necessary modifications to overhead line equipment (OLE) and power supply systems to enable infrastructure to incorporate ‘gaps’ in the OLE. It also includes outline proposals for an automated pantograph raising/lowering system.</td>
</tr>
<tr>
<td><strong>Abstract</strong></td>
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| This research, carried out on behalf of the Vehicle/Train Energy System Interface Committee, looked at the effect of ‘gaps’ in the DC conductor rail system and in the AC overhead line equipment (OLE). Physical gaps are formed in DC electrification where conductor rail lengths must be interrupted at features such as turnouts, crossovers, and level crossings – the size and frequency of DC gaps would be increased through the introduction of high performance switching system (HPSS) turnouts. Gaps in the AC OLE occur at neutral sections but would be greatly increased if discontinuous electrification is adopted in future OLE construction.  

The aim of this research was to determine the effect of additional electrical discontinuity created by ‘gaps’, on equipment within the train or at the trackside. The main outputs of this research are two reports; ‘Gaps in electrical conductivity of the 3rd rail DC traction system’ and ‘Gaps in electrical conductivity of the overhead line AC traction system’.  

The research determined that OLE featuring gaps is a feasible proposition that could significantly reduce the cost of electrification. In particular, where infrastructure has restricted clearance, or where junction areas can be simplified through removal of crossovers, which would benefit maintenance costs and improve mechanical independence of wired lines. The study has found no fundamental reason to prevent successful operation of a gapped OLE system, provided appropriate measures are adopted to mitigate risks identified in the report.  

Whilst it is apparent that widespread introduction of HPSS turnouts is unlikely, the benefit of this research will be realised if interruptions in the electrified OLE, whether physical interruptions in wiring, or effectively long neutral sections with extended earthed sections of contact wire, are adopted to reduce costs of future electrification. |
Abstract cont. The results of this research will inform future standards for infrastructure and operation, potentially allowing the industry to benefit from simplified OLE, or design for restricted clearance locations.

Since the adoption of HPSS is now unlikely on the GB infrastructure, it will not be necessary for the V/TE SIC to pursue further research. Gaps in the AC OLE system have the potential to reduce OLE costs and will be taken forward by the Future Electrification Group.

Published August 2010

Current Position This project is one of a suite of projects (T777 Understanding the effect of ‘gaps’ in electrical continuity of the traction contact system, T778 Feasibility study into raising and lowering pantographs while trains are in motion and T779 Energy storage systems for railway applications) that have explored various elements of ‘discontinuous’ or ‘discrete’ electrification, a concept where parts of an otherwise electrified railway are not provided with overhead wiring for cost reasons. Trains will either coast or be powered by batteries through ‘dead’ sections.

It is considered that ‘discontinuous’ electrification could help provide an economic solution for those routes where a more conventional solution would not be economic. This has been taken forward as part of the Energy Game Changer packages of work led by the V/TE SIC on behalf of the Technical Strategy Leadership Group as research project T966 The Technical Strategy Leadership Group’s ‘Energy Game Changer’.

An independently powered EMU (IPEMU) is currently being constructed and trialled by a consortium put together by the Future Railway team. In August 2013 the railway gazette published an article. In the article, the Director of the Future Railways Team said ‘by supporting this programme we are helping to take innovation out of the lab and de-risk its potential introduction onto the railway.’ For the full article see http://www.railwaygazette.com/news/single-view/view/independently-powered-emu-to-be-tested.html
**T778  Feasibility study into raising and lowering pantographs while trains are in motion**

**Description**

This research project has examined the feasibility of deliberately lowering and raising the pantograph while the train is on the move, in order to increase operational flexibility and potentially reduce delay.

**Abstract**

This research, carried out on behalf of the Vehicle/Train Energy System Interface Committee, looked at the acceptability of raising and lowering the pantograph while the train is moving, to determine whether the practice can be adopted generally. It looked at how the practice is used in some parts of mainland Europe, with apparent success, and considered the variety of pantograph types used on Network Rail infrastructure, together with the variety of OLE features with which they interface. The effect on each side of this interface and the effect on the combined system was also quantified.

The results of this research project have highlighted the key risks associated with raising and lowering pantographs while the train is in motion. It has shown that, using a bonded carbon design of carrier, the pantograph can be safely raised against plain OLE at speeds of up to 125mph (except in conditions with wind or ice), although the industry has decided that it does not currently plan to raise pantographs at speeds above 80mph.

The outputs of this research have informed future standards for infrastructure and operation. These will allow the industry to benefit from reduced delay at AC/DC interfaces, and give greater operating flexibility and reduced delay if trains are allowed to coast with a lowered pantograph to negotiate a section of damaged OLE. The cost of electrification may be reduced where coasting with a lowered pantograph is adopted to negotiate gaps in the OLE. This would reduce the complexity of wiring, and associated maintenance in junction areas or beneath limited clearance bridges.
The benefit of this research will be realised by developing manual or automated systems and associated operating practices, which ensure that pantograph movement is initiated only in plain line, avoiding specified OLE features. Accelerated pantograph life ‘type’ tests have been recommended, however the Future Electrification Group concluded that further testing would not be required since existing maintenance regimes will be used to identify any emerging abnormalities.

This project is one of a suite of projects (T777 Understanding the effect of ‘gaps’ in electrical continuity of the traction contact system, T778 Feasibility study into raising and lowering pantographs while trains are in motion and T779 Energy storage systems for railway applications) that have explored various elements of ‘discontinuous’ or ‘discrete’ electrification, a concept where parts of an otherwise electrified railway are not provided with overhead wiring for cost reasons. Trains will either coast or be powered by batteries through ‘dead’ sections.

Further consideration of discontinuous and discreet electrification has been covered as part of the Energy Game Changer packages of work led by the V/TE SIC on behalf of the Technical Strategy Leadership Group as research project T966 The Technical Strategy Leadership Group’s ‘Energy Game Changer’.

At the request of the rail industry, an additional rule has been included in the recent revision of the Rule Book module AC to allow electric trains to coast with lowered pantographs under certain conditions, with the potential to reduce costs and avoid disruption in these circumstances. This research has formed the basis of the justification for introducing this new rule.
**T779 Batteries and super-capacitors as energy storage for railway applications**

**Description**

Energy storage technologies have advanced over recent years, improving power and energy densities. This research investigated the potential use of these technologies on the railway for saving energy, improving performance, and enabling discontinuous and discrete electrification.

**Abstract**

On behalf of the Vehicle/Train Energy System Interface Committee, RSSB carried out an assessment of energy storage technologies for railway applications. Potential applications on the railways include: hybridisation of electric vehicles, battery powered vehicles, trackside applications on DC, and hybridisation of diesel vehicles. Electric vehicle hybridisation in particular has the potential to simplify electrification infrastructures, thereby reducing capital and maintenance costs. Although these technologies appear to be promising, a number of challenging factors remain, including high cost, limited life, size and weight.

The research was conducted in two phases. Phase 1 reviewed the existing propulsion and traction hybrid systems and energy storage devices. Phase 2 investigated the feasibility of discontinuous and discrete electrification schemes; and included the development of a computer simulation model, Energy Storage Systems for Railway Applications, that can be used to evaluate the behaviour of a train and energy storage devices.

The research concluded that discontinuous electrification is feasible. This is based on an assumption that savings in the initial electrification investment are substantial. To verify this conclusion a real application should be considered, to determine the possible savings, by comparing the cost of normal electrification with gapped electrification. The research also concluded that discrete electrification is difficult to justify.

If a new generation of energy storage devices is introduced onto the market and/or costs are reduced, the Future Electrification Group has agreed to review the findings.
T779 Batteries and super-capacitors as energy storage for railway applications cont.

Published

Phase 1 report published November 2009

Phase 2 report published October 2010

Current Position

This project is one of a suite of projects (T777 Understanding the effect of ‘gaps’ in electrical continuity of the traction contact system, T778 Feasibility study into raising and lowering pantographs while trains are in motion and T779 Energy storage systems for railway applications) that has explored various elements of ‘discontinuous’ or ‘discrete’ electrification, a concept where parts of an otherwise electrified railway are not provided with overhead wiring for cost reasons. Trains will either coast or be powered by batteries through ‘dead’ sections.
This project informed the understanding of overall performance and operational risk associated with the use of two pantographs, at running speeds up to 125mph (with varying distances between the pantographs, dependent upon train configuration).

On behalf of the Future Electrification Group, this research project has reviewed the overall performance and operational risk associated with the use of two pantographs, at running speeds up to 125 mph. The configurations of the units resulted in spacing between pantographs at pre-defined spacing of 43m, 130m and 217m, leading to different current collection profiles for different configurations when the trains are running at line speed.

Simulations were undertaken that considered the overhead line to pantograph interactions; using a verified tool (the simulator was part of the UIC sponsored EUROPAC project), at a variety of speeds up to a maximum line speed of 125 mph. An additional verification exercise allowed the results to be assessed against previous dynamic simulations and results from some physical Class 91 and Mk IV coach trials.

The research study concluded that the use of a pantograph head with low unsprung weight and employing conductors of higher tension would improve the current collection profile.

The results of the research will:

- Inform the understanding of overall performance and operational risk associated with the use of two pantographs, at running speeds up to 125 mph (with varying distances between the pantographs, dependent upon train configuration).

- Be used to investigate a range of potential improvements to pantographs or overhead contact line to enhance the current collection performance at pre-defined pantograph spacings.

- Inform the future system design requirements for new TSI-compliant electrification.
The research provided valuable information about the limitations of the existing overhead line systems on the future procurement of trains for two pantograph operation. The report will inform a possible route for future pantograph design.

Published

Published 2011

Current Position

This research project was undertaken to address the open point in the interface between pantograph and overhead line when running at high speed in multiple configuration on existing 25kV AC overhead line electrification system. The research project outputs have informed:

- The future procurement of trains to run on legacy 25kV AC overhead line electrification.
- The future development of the lightweight pantograph specifically designed to work on legacy 25kV AC electrification systems.
- The design parameters for future 25kV AC electrification systems.

The industry, supported by the V/TE SIC is undertaking further work and trials of modified pantographs to enable good current collection at higher speeds on existing infrastructure. The V/TE SIC proposes to support work on active pantographs, which could lead to a further work-stream under the leadership of the Future Railways team.
RSSB was a member of an EC consortium looking at ways of reducing the costs and time taken to achieve trans-European rail vehicle certification. This research project addressed RSSB’s contribution in the area of pantographs.

PantoTRAIN is one of three projects within TrioTRAIN (a European FP7 project). The aim of the projects was to propose an innovative methodology that will allow multi-system network and route approval in Europe to become a faster, cheaper and better process for all stakeholders involved.

The PantoTRAIN project proposed to transfer rolling stock certification work away as much as possible from the current use of physical testing, to simulation. The aim of the research was to develop innovative methods and processes for software-aided certification of vehicles and components capable of reducing the number of physical tests, the overall certification time, the associated costs and the influence of uncontrolled conditions.

On behalf of the Vehicle/Train Energy System Interface Committee (V/TE SIC), RSSB contributed to 3 of the 6 work packages within PantoTRAIN. This contribution included:

1. Analysing the key parameters affecting the accuracy of pantograph / catenary numerical models. This task was part of the measurements of criteria to build and validate pantograph / catenary numerical simulation tools.

2. Leading the new innovative pantograph designs with control functionalities activity and contributing to the pantograph structural optimisation and homologation of a mechatronic pantograph tasks.

3. Liaising with the European Railway Agency and National Safety Authorities and targeting the dissemination of information, proposals for integrations to existing standards and homologation processes and their assessment for safety, and quality and practical feasibility. These tasks were part of the quality assurance and regulatory acceptance activity.
The main deliverable for this research is a summary report that provides a generic high-level view of the overall project and research findings (the interim technical deliverables are available to RSSB members via SPARK).

This research has concluded that Hardware-in-the-Loop (HiL) testing can be used to support the certification of pantographs in addition to line tests and software simulations. The work package 1 report provides procedures on how to support EN50318 in order to validate the pantograph-catenary simulation tools for virtual certification.

The results of this research will inform plans to investigate the development and use of a HiL testing facility in GB. The findings have been communicated to the V/TE SIC and members support the development of this type of facility.

This research was aimed at developing and introducing a computer-aided certification process to allow the reduction of the time and cost of pantograph certification against ENs and TSIs by transferring current physical track tests to laboratory testing and numerical simulation. It established that to use virtual testing for certification, the methodology needs to be defined and validated. Taking into consideration the continuous development of computer capacity and numerical tools, virtual testing represents a future opportunity.

This research project concluded that Hardware-in-the-Loop (HiL) testing can be used to support the certification of pantographs in addition to line tests and software simulations. The advantage of the HiL testing compared with line tests is the reduction of the number of line tests and costs for the certification of pantographs.

The V/TE SIC has commissioned a new research project to develop the business case and support any decisions for the development of a GB owned HiL testing facility, Simulation tool and new test facility (T1039 Economic assessment of a GB based pantograph/overhead line testing facility).
T873 Impact of higher 25kV fault currents

**Description**  
This research has investigated the affect of higher currents (increased fault currents) on touch potentials and induced voltages, and the way other industries and countries solve the issue of higher AC currents.

**Abstract**  
On behalf of the Future Electrification Group (FEG) and Vehicle/Train Energy System Interface Committee (V/TE SIC) this research has investigated the risks associated with higher currents flowing in the electrification infrastructure system under fault conditions; and the impact this has on human beings, livestock and susceptible systems such as signalling and telecommunications. The consequences of raising the fault levels need to be understood, and any mitigation measures identified, that are needed to maintain a safe system that complies with relevant Network Rail standards and BS EN 50122-1. The Euro Norm ‘EN 50388’, 2005 Clause 11.2 specifies 15kA as the maximum fault current which rolling stock and new infrastructure will be built to withstand. However, the 12kA value has been commonly used and therefore defined as a nominal fault current. In future it is proposed, irrespective of the fault current value, that a 15kA fault level is applied, with appropriate risk assessment and mitigation measures.

This research has reviewed earthing standards and codes of practice related to touch potentials from a range of administrations and organisations, including BS EN 50122-1:2011, National Grid, Electricity Networks Association, and railway design specifications (HS1, DB, and SNCF). A risk-based assessment for step and touch potentials was also carried out, taking into consideration the requirements of both human protective provision and equipment functionality. The research also reviewed a range of standards and codes of practice to gain an understanding of how safe levels of step and touch potential are maintained on different electrical systems and then reviewed the risk process, which allows higher fault levels to be used on other railways, to assess its suitability for Network Rail infrastructure.
The research has concluded that the use of additional mitigation measures (risk process) would be an acceptable way to achieve compliance on GB railways, subject to appropriate earthing requirements. This will allow segregation limits for signalling, infrastructure, and electrification sites can be relaxed, subject to site-specific design requirements. The key benefits of this research will be realised through the reduction in the cost of future electrification of the GB rail network and improvements in the performance of trains.

Published October 2011

The industry, spearheaded by the V/TE SIC and Network Rail, is using the findings to reduce the cost of future electrification of the GB rail network and improve the performance of trains.

The FEG and V/TE SIC will implement the findings from this research by supporting the draft Railway Group Standards GM/RT2111 – AC Rolling Stock Subsystem Interfaces to Energy Subsystem, GM/GN2611 – Guidance on AC Rolling Stock Subsystem Interfaces to Energy Subsystem, GM/RT2113 – DC Rolling Stock Subsystem Interfaces Energy Subsystem and GM/GN2613 – Guidance on DC Rolling Stock Subsystem Interfaces to Energy Subsystem.
This research, carried out on behalf of the Vehicle/Train Energy System Interface Committee (V/TE SIC), was done in order to resolve an open point in the Conventional Rail Locomotives and Passenger Rolling Stock Technical Specification for Interoperability (CR LOC & PAS TSI).

The CR LOC & PAS TSI and Conventional Rail Energy Technical Specifications for Interoperability (CR ENE TSI) will now permit the use of plain carbon or metallised carbon collector strip material, as this research has demonstrated that, in terms of wear characteristics, the performance of the two types of carbon strip is similar. There was also concern for the effect on wear characteristics that may be caused by operation of TSI compliant and domestic vehicles if the carbon collector material alternates between plain or metallised types.

A pan-European research project, involving a number of railway administrations and a university, was formed under the co-ordination of the UIC. RSSB was a participating member of the project, on behalf of the V/TE SIC and the GB CR ENE TSI Working Group. This research carried out laboratory-based tests to identify the best choice of pantograph collector material at the interface with a contact wire of hard drawn copper, or other copper alloys used in Europe, and establish the effect of mixed collectors.

By reducing the number of contact strip types it was thought that it may be possible use a single pantograph across many areas of Europe, to reduce maintenance costs as well as optimise maintenance procedures. Further significant cost benefits may also be achieved by extending the useful life by an informed choice of contact strips.
Abstract
The main deliverable for this research project is a report that provides a summary of the tests carried out and the main conclusions and recommendations drawn from the analysis of results. This research has concluded that there is no significant difference in terms of contact wire wear between plain and metal impregnated carbon contact strips up to a metal content of 35% in mass (the highest level fully tested). The results of this research will inform updates to UIC leaflets 608 and 794-1, will inform EU standards EN 50367 and 50149, and will resolve the open point in the CR LOC & PAS TSI.

Published
November 2012

Current Position
The research recommended that further work should be carried out at a European level to determine the methods to characterise carbon materials used in contact strips for pantographs if it is required to further standardise contact strip material. This project acquired a substantial understanding of the interface between the contact strip and the overhead line but was not able to determine an appropriate test.

The GB Rail Industry predominantly uses metal impregnated carbon strips. This research has found that plain carbon strips are as good for current collection and have little or no impact on contact wire wear compared to metallised carbon.

The V/TE SIC has noted the potential benefit to GB operators of using plain carbon and recommends that operators should consider this subject to further research on lifespan impact and agreement with relevant partners.
T950 Investigating the economics of the 3rd rail DC system compared to other electrification systems

**Description**

This research project carried out a high-level assessment of whether it would be prudent to convert from the existing 750V DC system to 25kV AC system, from an economic and technical perspective.

**Abstract**

This research, carried out on behalf of the Future Electrification Group (a sub-group of Vehicle/Train Energy System Interface Committee (V/TE SIC)), has considered the long-term options for modification or replacement of the 750V DC third rail electrification system. This is used over a significant part of the UK main line network and this work was to determine whether there is a prima facie case on economic grounds for conversion to 25kV AC overhead electrification; and if so, over what approximate period this conversion could practicably be carried out.

The research considered appropriate options for future power source(s) on DC routes where renewal dates for these routes are in the short- to medium-term. The options considered were:

- Modification of existing DC system
- Conversion to an alternative DC system
- Replacement with an AC system

As part of this research a desk top study was undertaken for two example routes, looking into infrastructure issues, rolling stock conversion, signalling compatibility, and energy efficiency.

The main deliverable for this research is a report that provides a (national) generic high-level business case for conversion from 750V DC to a 25kV AC electrification system. This research has concluded that the potential benefits of changing to a 25kV OLE system are:

- Cost reductions in the capital investment of installing an AC system when compared with a DC system.
- Reduced energy losses and carbon footprint for ‘like for like’ service (comparing the same 4-car EMU service with AC and DC). Results also indicate that an equivalent AC service consumes at least 20% less energy.
Abstract cont.

- Increased power, enabling higher average speeds, increasing capacity and as a result, reducing journey time by 3–5% (on average).

- Reduction in safety risk to unintended trespassers from possible electrocution.

This research has provided valuable information about the economics of the third rail 750V DC system compared with the 25kV AC electrification system. The results of this research will inform Network Rail plans for the next and subsequent Control Periods (CP5 and beyond) and inform the industry decision on what the most appropriate future strategy for the 750V DC third rail system should be. Any possible future work is likely to start during CP5, taking around 15 years to complete. The findings have been communicated to various rail industry groups including the Technical Strategy Leadership Group, V/TE SIC and Planning Oversight Group. The GB rail industry is considering the research findings in the context of its longer term strategy and planning.

Published August 2011

Current Position

The High Level Output Specification (HLOS) 2012: Railways Act 2005 statement published by the Government in July 2012 included a number of proposals for new electrification schemes. One of these is for an “electric spine” route from Southampton to the Midlands, which includes the conversion of the line from Southampton to Basingstoke to AC that would enable the concept to be proved. Funding would also be available in CP5 to allow design work to start on other routes.

The issues surrounding conversion of AC/DC routes was investigated further in research project T991 Requirements and optimisation of AC/DC changeover sections. This project was designed to explore some of the human factor and technical issues associated with rolling stock and infrastructure that need to be considered in regular changes between DC- and AC- based systems.
**T951 Investigation of the Automatic Power Control magnet and receiver system interface**

**Description**
This research project has investigated the flux density around the air gap at the Automatic Power Control magnet on the trackside and its interface with the Automatic Power Control receiver on the train, to inform the development of the Energy Railway Group Standard.

**Abstract**
The Automatic Power Control (APC) magnet/receiver system is used to ensure that circuit breakers open before a train reaches a neutral section of the overhead line electrification infrastructure and then re-close on exit from the neutral section. To date the information available on the interface remains insufficient and is not fully defined and documented. Failure of the system can result in flashovers as the train draws current when it moves into the neutral section, potentially resulting in damage to both the train pantograph and the infrastructure. Trains that cause repeated flashovers may be removed from service for checking. This could result in operational delays. For infrastructure neutral section locations, both response by emergency teams and subsequent replacement carry a cost in terms of resources and network delays. With the introduction of new magnets and receivers, as a result of technology changes, there is an increased risk that an incorrectly specified or undocumented system could be set up, resulting in failures.

This research project, carried out on behalf of the Vehicle/Train Energy System Interface Committee (V/TE SIC), has investigated the existing APC magnet/receiver system and defined a set of performance requirements. RSSB has undertaken this research with the aim of providing informative technical analysis to support the creation of a new standard.

This work and its outputs align with key industry goals for future electrification and will address hitherto open points within energy standards.

As part of this research bench tests were carried out to characterise the magnetic flux patterns from the newly introduced ‘white’ APC magnet. The main deliverable for this research is a report that provides key requirements to address the open points within the forthcoming energy standards and the outputs align with key industry goals for future electrification.
**Abstract cont.**

This research has concluded that if the APC system is set in accordance to the parameters, then the overall reliability of system operation is 99.9% under the normal limits of operation on the current railway assuming that the magnet and receiver have not failed. This research has provided valuable information about the requirements for the APC system element of the forthcoming Energy RGS. The results have already been utilised to populate the key requirements within these documents. The findings have been communicated to various industry groups including V/TE SIC and the relevant outputs will appear within the documents forming the forthcoming Energy RGS.

**Published**

August 2012

**Current Position**

The research project has determined the necessary basic parameters of the APC system to allow analysis of the magnet receiver interface. The outputs from the project have been used by RSSB to inform the forthcoming Energy RGS. With respect to placement of APC on dual electrified areas, the project has identified some areas of conflict between the APC required for AC vehicles, and the DC electrification system that can be removed by appropriate design.
<table>
<thead>
<tr>
<th><strong>T966  The Technical Strategy Leadership Group’s ‘Energy Game Changer’</strong></th>
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<tr>
<td><strong>Description</strong></td>
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| **Abstract** | In considering the 30-year Rail Technical Strategy (RTS) for GB, the Technical Strategy Leadership Group (TSLG) identified energy use as one of the five key ‘game changer’ issues that the industry will face. This research programme carried out an assessment of the key energy initiatives in order to inform the Energy Strategy elements of a revised and updated RTS.  
On behalf of the TSLG and under the guidance of the Vehicle/Train Energy Systems Interface Committee, this programme of research explored the case across five different initiatives: energy risks, lower cost electrification, discontinuous electrification, line speed profiles and in-service train length adaptation.  
The Energy Strategy brings together a range of technical innovations in a single integrated strategy which seeks to: understand the risks associated with the future supply of energy; provide guidance on how to reduce the cost of electrification; reduce energy demand; and reduce carbon emissions. It was estimated that a 1% reduction in traction energy use would be worth £7m in savings per year; while electrification brings benefits to operational cost, capacity, journey time and reliability, as well as carbon footprint.  
This research project has utilised the skills of a combination of industry stakeholders from across GB, internal RSSB resources, and rail industry consultants to carry out the work under the coordination of RSSB. The research has involved interviews and workshops with industry experts, supported by a large amount of desk-based study, modelling and cost benefit analysis where necessary. In the case of the energy risks work this included the identification and review of over 130 sources of information. |
### Abstract

All of the deliverables will be available via SPARK. Additionally the main energy risk report is available on the RSSB website. The risk report provides an overview of the key questions and issues raised in discussions around future security. The research has concluded that rail energy costs are likely to rise from £500m to £800m by the end of Control Period 5 (CP5). Taking into account non-traction energy required to power stations, depots and other rail infrastructure, the annual energy bill is likely to be £1bn thereby increasing the importance of energy saving initiatives. The findings have led the cross industry Vehicle / Train Energy System Interface Committee (V/TE SIC) to the conclusion that, even with uncertainties around supply and expected cost increases, electricity will continue to be the most viable (and green) energy source. This research has provided valuable information about the economics, risks, and technical drawbacks of energy security, based on the current infrastructure and it will inform the future RTS.

### Published

August 2012

### Current Position

This research programme informed the development of the Rail Technical Strategy, published in 2012. More generally, this programme has informed debate at TSLG around how the industry can improve its energy performance in the long-term. It is complimentary to other TSLG work streams such as the development of train regulation systems for the future.

This work has informed the ‘Alternative Solutions to Delivering Passenger Demand Efficiently’ Route Utilisation Strategy which explores options for carrying passengers on some parts of the network more cost effectively. It builds on the Geographic and Network RUSs (Electrification and Passenger Rolling Stock) published in July 2013.
Among other things, it considered alternative methods of delivery of electric traction on lower density lines by looking at:

- Ways to deliver additional capacity and connectivity into city centres in a cost effective manner
- Ways to provide cost effective OLE on less used parts of the network
- Ways to cater for growth and provide cost effective rail services on less used sections of the railway

This work has also brought to TSLG’s attention, developments by suppliers and universities around battery technology developments, for which a watching brief is now maintained. The work has also informed V/TE SIC’s response to the Office of Rail Regulation’s (ORR’s) 2013 periodic review.

The industry Sustainable Rail Programme (managed by RSSB), continues to investigate areas of energy and carbon reduction potential. One area of work undertaken (T1002 Identifying best value carbon reduction interventions and development of a non-traction energy forecast) was the identification of efficiency interventions required to deliver the greatest carbon and cost savings in CP5 and CP6 beyond grid decarbonisation, fuel change and electrification. The Energy Game Changer research helped to inform this programme of work.

Through the electrification research, the concept of asymmetric autotransformers arose which was explored under RSSB research project T987 - Feasibility of an asymmetric auto transformer electrification system.

As this programme of work was progressed, Network Rail developed proposals for the establishment of an Energy Services Team.
T987  Feasibility of an asymmetric auto transformer electrification system

Description
This research project has investigated the operational requirements, technical characteristics, and issues surrounding the use of an asymmetric auto transformer to support potential implementation in future railway electrification schemes.

Abstract
On behalf of the Future Electrification Group, a sub-group of the Vehicle/Train Energy System Interface Committee, RSSB carried out an in-house theoretical investigation to assess the feasibility of asymmetric auto transformers in terms of power capacity, performance, and cost.

Asymmetric auto transformer (AAT) is a 25kV electrification system that supports standard AC trains and offers larger power capacity compared with a normal auto transformer (AT) system. It enables a reduction in the number of feeder stations required whilst maintaining the same power density. AAT also allows longer feed sections, and this would enable planners to overcome challenging routes where there is no access to grid feeding points.

The research has been conducted in three phases. The first phase determined the AAT system capacity, compared it with a normal AT system, and determined maximum distances between feeder stations. The second phase assessed the performance of AAT systems in terms of touch voltages, magnetic fields, resonance and harmonics distortion, and interference in signalling and telecoms equipment. The third phase assessed the cost of AAT systems and compared it with a normal AT system.

This research has concluded that feeder station spacing can be increased compared with normal AT systems. For example, an AAT system based on 132kV would offer more than a one-third reduction in the number of feeder stations. In addition, the analysis showed that the technical performance of AAT systems is similar to a normal AT system. The economic appraisal also showed that the cost of AAT is comparable to a normal AT system.
**T987 Feasibility of an asymmetric auto transformer electrification system cont.**

**Published**  
October 2013

**Current Position**  
This research concluded that two basic AAT configurations are possible, 132kV and 220kV. An AAT system based on 132kV would be the most suitable, given 220kV switchgear and equipment are considerably more expensive. The Future Electrification Group (FEG) agreed that the recommendations to carry out an assessment of alternative AAT system and supply configurations (such as use of 2-phase 132kV) should be investigated further. Additionally, to carry out an assessment of the increased power demands on the high voltage network grid to determine the levels of negative phase sequence.

Research project **T1061 Exploring the prospects of 25kV static Converter feeder station** has been commission to investigate improving the performance of AC railway, reducing the cost of electrification, and addressing the issue of increased load demand. The research will explore the possibility of replacing the existing 25kV feeder station traction transformer with a power electronics based static converter, and also minimise the switch gears requirement.
## Description
This research investigated the potential impact that the new TSI voltage and current limits may have on existing rolling stock under normal and fault conditions operating on new and upgraded electrified routes.

## Abstract
The GB electrification network currently consists of a mixture 25kV AC overhead line (OHL) systems and 660/750V DC third rail systems. However, the new Energy Technical Standard for Interoperability (ENE TSI) has been issued with references to Euronorms for higher voltage and maximum fault current limits, and the Locomotive and Passenger TSI (LOC & PAS TSI) now requires all new 25kV-capable GB rolling stock to be compliant with greater maximum system voltages and fault currents than previously.

On behalf of the Vehicle/Train Energy Systems Interface Committee, this research investigated the potential impact that applying the TSI voltage and maximum fault current limits may have on existing rolling stock under normal and fault conditions.

While regenerative braking already delivers benefits in terms of reduced energy consumption and reduced wear on brake equipment, running rolling stock at higher voltages offers further potential benefits:

1. Higher voltage limits will result in lower transmission losses for both AC and DC systems.
2. Rolling stock that operates at higher voltages could make increased use of regenerative braking.
3. Reduced energy consumption would also mean a reduction in the carbon emissions associated with using that energy.

Although the TSI only requires compliance from new rolling stock, recognition of these potential benefits means it could be beneficial to operate existing rolling stock at higher fault levels as well.

This research concluded that increasing the allowable regeneration voltage to 29kV should be done on a route specific basis for those classical and UK1 routes having an impedance sufficiently low to be viable for regenerative braking. The findings from this research project will be built into the TSI Implementation Strategy, which is being developed by the Future Electrification Group and will be considered in upcoming Network Rail electrification schemes.
<table>
<thead>
<tr>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>T1001 Review of existing rolling stock against</td>
<td>The research project has highlighted rolling stock which is incompatible with future TSI compliant lines. These outputs will be utilised to draft the</td>
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<tr>
<td>new and upgraded electrification compliant with</td>
<td>future rolling stock strategy for GB and also the output can be utilised for network change impact discussions in future.</td>
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<tr>
<td>the Energy TSI cont.</td>
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**Published**  
February 2014
## T991 Requirements and optimisation of AC/DC changeover sections

### Description

This research project will carry out an in-depth analysis of the technical factors associated with both rolling stock and infrastructure that need to be considered in changing from a DC- to AC-based system, and provide the industry with the information necessary to make informed decisions in optimizing the AC/DC conversion process.

### Abstract

The research project T950 Investigating the economics of the 3rd rail DC system compared to other electrification systems considered the long-term options for modification or replacement of the 750V DC 3rd rail electrification system and it concluded that 25kV AC OLE was the best, primarily because of energy efficiency, but also because of the associated benefits from increased train performance, the potential for additional capacity, signalling immunisation, reduced carbon emissions, and other technical improvements.

However, implementing a replacement of the existing DC 3rd rail electrification system with AC OLE will raise a number of technical challenges including a significant increase in the number of changeover sections on the network. A major concern is that if these changeovers are not well situated and optimised to reduce stray current then there is the risk that they could result in the malfunction of trackside infrastructure and equipment, and metallic infrastructure. Stray currents may even lead to the track itself acting as a sacrificial anode, corroding away relatively rapidly.

This research project will carry out an in-depth analysis of the technical factors associated with both rolling stock and infrastructure that need to be considered in changing from a DC- to AC-based system, and provide the industry with the information necessary to make informed decisions in optimising the AC/DC conversion process. It will also cover the cost, human factors and safety implications that infrastructure managers and rolling stock owners and train operators need to be aware of. The project will also investigate systems from GB as well as the rest of Europe, and results will help to optimise the changeovers. The results will also inform work being undertaken by Network Rail as part of the Governance for Railway Investment Projects (GRIP) programme that is taking forward the industry results from T950.
## Abstract

Early analysis has highlighted that through the results of this research, a cost of around £2.8 - 7.8m could be avoided. The costs avoided reflect the decreased likelihood of costs associated with remedial actions and equipment damage that could occur if changeovers are not designed in an optimised way. Furthermore, a significant benefit of AC/DC crossover optimisation is reduction of the corrosion caused to railway infrastructure by stray currents.

## Published

In progress

## Current Position

This project is progressing and is expected to be completed by Summer 2014.
### Description
This research project will establish an analytical basis for identifying the optimal sub-sectioning distance of AC electrification in different service and line scenarios that trade-off the operational and safety benefits of sub-sectioning against its costs.

### Abstract
Historically sub-sectioning associated with AC electrification was provided at 10 to 15 km intervals as a norm, mainly for protection. However, it is important to understand whether this distance is the optimal switch sub-sectioning distance that adequately trades off the operational and safety impacts against the cost of sub-sectioning. Currently there is no analytical basis for arriving at an answer to that question, which means the industry continues to use an experience-based and ‘one-size-fits-all’ approach, and struggles to justify decisions on sub-sectioning lengths in different conditions and scenarios.

On behalf of the Future Electrification Group, a sub-group of Vehicle/Train Energy Systems Interface Committee, this research project will establish an analytical basis for identifying the optimal sub-sectioning distance in different service and line scenarios that trade-off the operational and safety benefits of sub-sectioning against its costs. It will develop analytical models and guidance that take the different input variables associated with a service and a line, such as headway and average speeds, and identify the optimal sub-section distance for that scenario.

By establishing an analytical basis for switch locations and sub-sectioning distances, the work will support Network Rail and other industry stakeholders in their decision making and design processes. This will allow the industry to improve the efficiency and effectiveness of existing switches (by identifying optimal sub-sectioning distances as opposed to engineering dynamics) when upgrades, renewals, and switch replacements are being planned.

### Published
In progress

### Current Position
This research is progressing and is expected to be completed by Autumn 2015.
The aim of this research is to identify the quasi-static force and frictional hysteresis for the main types of pantographs currently in use in GB.

To ascertain the interaction between a new design of overhead line equipment (OLE) or pantograph, simulations are carried out. The accuracy of the simulation outputs is dependent upon the accuracy of the models of the pantograph and OLE. For the pantograph this model is generated by bench testing a new pantograph. Whilst this practice gives a good correlation with the forces measured during line tests it gives no indication of what forces will be generated in an operational pantograph.

There are currently five types of pantograph being used in GB. The performance of these pantographs will vary because of different working conditions and the increase in friction that will occur between the overhaul of the pantograph. As simulations are carried out using a new pantograph the forces predicted are considered to be optimistic and unrealistic for the majority of the life of the pantograph.

On behalf of the Future Electrification Group, a subgroup of the Vehicle/Train Energy System Interface Committee, the aim of this research is to identify the quasi-static force and frictional hysteresis for the main types of pantographs currently in use. This will be derived from accurate measurements of the quasi-static contact force and frictional hysteresis as described in IEC 60494-1: Railway applications - Rolling stock – Pantographs - Characteristics and tests - Part 1: Pantographs for mainline vehicles.

The research will provide the knowledge needed to define the performance of a typical pantograph. The results of this research will support Network Rail to optimise the OLE design that reflects the typical pantograph, thereby reducing the overall wear both on the overhead contact wire and pantograph. Reduction of wear on the pantograph and OLE is expected to reduce dewirements and the associated service delays.

In progress

This research is progressing and is expected to be completed by Summer 2014.
T1039 Economic assessment of a GB based pantograph/overhead line testing facility

**Description**
The research will determine the feasibility of GB investing in simulation software and test facilities by quantifying the costs and benefits. It will establish whether there is a business case that supports future funding and development.

**Abstract**
Further to RSSB project T849, PantoTRAIN - Pantographs: total regulatory acceptance for the interoperable network, the Vehicle/Train Energy System Interface Committee identified the need to examine the case for having a hardware in loop (bench) testing facility in GB. In parallel, the Great Western Mainline electrification stakeholder group has also identified the potential for having a GB based pantograph / overhead line interaction simulation tool and an in line testing facility.

Hardware-in-the-loop (HIL) testing, also referred to as bench-testing, can be used to support the certification of pantographs in addition to line tests and software simulations. The advantage of HIL testing is that it reduces the number of costly in-line tests that need to be undertaken for the certification of a pantograph. HIL testing is more representative compared to software simulations, providing the advantage of physical tests with the actual pantograph while eliminating most of the uncertainties associated with the mathematical modelling of pantographs.

The GB rail industry makes extensive use of existing European facilities such the SNCF’s OSCAR simulation tool, Polimi’s HIL facilities, and DB’s line-testing facilities. Relying on European facilities however, has a number of drawbacks for the GB rail industry including: higher transportation costs, difficulties in testing GB specific setups, and the lost opportunity to develop industry learning through GB performing its own testing.

Industry members have proposed that the GB rail industry develop and enhance its own capabilities. However, these can be expensive to establish and maintain. The purpose of this research is to determine the feasibility of investing in these facilities.
| **Abstract cont.** | The GB rail industry would benefit through reduced cost and turnaround times for conducting tests, an increase in industry capability and learning, and further economic benefits such as developing future skills in the GB rail industry and the possibility of providing alternative and potentially enhanced pantograph testing and certification to the rest of Europe. |
| **Published** | In progress |
| **Current Position** | This research is progressing and is expected to be completed by Spring 2015. |
T1051 Investigation into the effects of applying the Physical Agents (EMF) Directive in the UK railway system

Description
This research will determine what effect the Directive relating to Physical Agents (EMF) might have on Railway Group members, by reviewing operational processes that expose their staff to electromagnetic fields.

Abstract
European Directive 2004/40/EC regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) was adopted but never fully implemented by many member states, including the UK. Significant concerns were raised that it contained requirements that would have been disproportionate in some instances. A revised Directive 2013/35/EU repeals the 2004 Directive and contains updated technical annexes setting out Exposure Limit Values.

The Directive includes requirements for work place risk assessments, control of exposure (with stated action values and exposure limits), appropriate health surveillance, information, working instructions and training for affected workers. European Member States are required to transpose the Directive into their respective national legislation by 1 July, 2016. However, the requirements must be applied retrospectively. The EU intends to publish a ‘practical guide’ early in 2016, supporting the Directive but this will be too late to prepare for implementation.

On behalf of the Vehicle/Train Energy System Interface Committee, this research project will review the work undertaken to consider the effects of the 2004 Directive on the UK rail industry, and to consider how the revised Directive will impact upon the rail industry.

The initial stage of the project will consider the previous work and identity if the conclusions remain valid, or to determine what additional work is necessary, and finally how this can be used to support the rail industry.

This research will:

• Demonstrate whether the railway has any EMF risks at a general industry level that require specific management
• Produce a generic approach that can be used to address areas of concern, should they arise
• Make recommendations for further research that will cover more detailed requirements.
# T1051 Investigation into the effects of applying the Physical Agents (EMF) Directive in the UK railway system

<table>
<thead>
<tr>
<th><strong>Abstract</strong></th>
<th>The main benefit of this research will be to ensure that EMF risks are properly identified and managed by the industry, which will help railway undertakings to avoid the duplicated effort of individually reviewing and risk-assessing the impact of the new Directive, and reassure employees that they are working in a safe environment. Therefore the benefits are expected to be the avoidance of resources being wasted through risk assessments being undertaken independently by each employer.</th>
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<tr>
<td><strong>Published</strong></td>
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<tr>
<td><strong>Current Position</strong></td>
<td>This research is progressing and is expected to be completed by Winter 2015.</td>
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Where can I find research?

All the research outputs that have been published since RSSB began its programme can be found on the Research Project Catalogue page:

http://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue

If you know the reference number for the project – eg TXXX – you can use the Search field at the top of the projects list to find it. Alternatively enter a keyword in the Search field to find all the projects with that word in their title.

The previous pages contain listings of the published and current Energy projects – correct at the time of publication.

We hope this helps you find the information that is most relevant to you.

If you can’t find what you’re looking for, please contact us – enquirydesk@rssb.co.uk
Each project has a research brief that provides a concise summary.
Where can I find research?

SPARK provides a way for the rail sector and others to work together and share knowledge more efficiently on-line, with the aim of reducing duplication, speeding up innovation, and maximising value.

Researchers, innovators, and decision makers across the rail community are able to upload and share information via SPARK so other users can find out what is known and who knows it, and this creates opportunities for networking and cooperation.

In partnership with UIC, RSSB is enhancing SPARK to create an even bigger on-line ‘knowledge sharing community’, drawing on the combined wisdom from railway administrations and centres of excellence from across the globe.

During this enhancement phase, access to SPARK will continue to be available to RSSB members, knowledge sharing partners and registered researchers in the Rail Research UK Association. From early 2013 new access levels will be available, including that of ‘reader’ which is open to all.

Register for access to SPARK at:
http://www.sparkrail.org

find it - learn it - share it

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International organisations
Rail organisations
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If you have enquiries about research contact the RSSB Enquiry Desk – enquirydesk@rssb.co.uk, tel 020 3142 5400