Research Brief

Investigating the economics of the 3rd rail DC system compared to other electrification systems

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Introduction

This research was sponsored by the Future Electrification Group (FEG), and its parent body, the Vehicle/Train Energy System Interface Committee (V/TE SIC).

Electrification of the main line network was started in the early 20th Century and employed a wide range of distribution systems. The need for common standards has been the subject of government and industry study in the UK since at least 1920. The most recent comprehensive report was published in 1955. It recommended that 25kV AC be adopted as the standard for all future main line electrification on the grounds of its higher energy efficiency, ability to support higher speeds and higher capacity. Nevertheless, the UK still uses nearly as much 3rd rail system as the rest of the world put together.

This research supports the evidence base for short- to medium-term decisions about the renewal of electrification infrastructure, and contributes to the goals of improving business performance and reducing unnecessary costs. It also contributes to the Energy Strategy 'game changer' identified under the auspices of Technical Strategy Leadership Group (TSLG) and supports the rail industry's Sustainable Development Principles.

The issue addressed is the long-term future of the 750V DC 3rd rail electrification system used on a majority of routes south of London. An opportunity is presented by the need for renewal of the DC distribution equipment in substantial areas of the network within the next ten years. The high energy losses associated with this system, the need for upgrades driven by minor changes in timetabling, and its susceptibility to disruption in ice and snow suggest that alternatives to the DC electrification system should be considered. This represents a once in 40 years opportunity.

This research, though started independently, and before the House of Commons Transport Select Committee raised the issue of 3rd rail winter performance during its review of the impact of winter weather on the UK transport network, is likely to form the basis of the industry's response in relation to the 3rd rail issue.

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This has been recognised by the National Task Force which is leading the railway industry's response.

Aims

The objective of the research was to consider long-term options for modification or replacement of the 750V DC 3rd rail electrification system, to determine their technical and economic feasibility and to present a preliminary economic case for the preferred option, with an indication of timescales for conversion.

The alternative electrification options agreed at an initial stakeholder workshop and considered during the course of the research were:

- Modification of the 750V DC system to use a bottom contact or side contact third rail.
- Conversion of the DC system to overhead distribution at 1.5kV or 3kV.
- Replacement of the DC system with overhead distribution at 25kV AC.

Findings and benefits

Modification of the 3rd rail system to bottom or side contact would be very expensive because of the need to clear lineside structures, including bridge girders and platforms, to provide more space for the conductor rail and shoegear. This option would offer only winterisation benefits. Conversion to any form of overhead electrification would offer significant additional benefits in the form of reduced track maintenance and renewal costs, some improvement in energy efficiency and a reduction in the risk of electrocution. However the energy efficiency improvement delivered by 25kV overhead electrification is very much higher than the other options. It is in the order of 20% at the supply point. This represents a very large potential gain to the industry.

Of equal importance to the energy efficiency gain is the potential for the 25kV AC system to sustain the substantial increases in electrical demand which are likely to be needed to deliver additional passenger and freight capacity in the future, compared with the 3rd rail DC system which is approaching its limits in terms of ability to deliver power to high-frequency services over lengthy routes.

The estimated capital costs of replacement of the 3rd rail system with 25kV AC overhead are less per track kilometre than full renewal of the 3rd rail system, even taking into account the need to provide additional clearance through bridges and tunnels. However, for operational reasons the replacement would have to

be carried out on a 'line of route' basis, which may mean some DC equipment being replaced before it is life expired, so there will be some increase in costs in the short-term. Costs of signalling immunisation are relatively small.

About 25% of all DC rolling stock is already dual voltage (750V/ 25kV) and a further 40% is designed for easy conversion, requiring only the addition of pantograph, transformer and controlled rectifier, set in space already provided. The balance of rolling stock will require special provision and may not be worth conversion, considering its remaining life. In most cases the older rolling stock is likely to be replaced during the envisaged conversion timescales.

An outline implementation strategy and insertion plan have been developed which suggest an 'outside in' approach consistent with the patterns of use of dual voltage and readily convertible rolling stock, starting at the extremities of routes away from London and working inwards. Complete conversion of the network would take a minimum of 15 years and would need agreement of a common strategy with Transport for London, allowing for the areas of overlap with London Underground.

In summary, the findings of the research project are:

- Reduced cost - The costs of running a DC electrified railway are well in excess of an equivalent AC electrified railway, taking into account energy usage (including losses), maintenance and renewals. Research by Network Rail and train operators has quantified the high electrical losses associated with the 3rd rail system, particularly on relatively long distance routes.
- Increased performance - 25kV AC allows the train to accelerate faster, giving an average time saved for a stopping service in the region of 3-5%. The improved performance could also be used to relieve congestion or provide better perturbation recovery.
- Increased capacity - the 25kV AC system would support expected future increases in passenger demand, allowing for increased energy consumption by as much as 50%, whilst an equivalent upgrade to the current DC system would not be economic.
- Technical - The DC system poses more challenges as it gets upgraded because of the thermal capacity limitations of the current equipment. These challenges can only be addressed by providing more paths for the current flow;

however terminating those paths is very challenging. For main line purposes 3rd rail is a technically obsolete system.
- Improved safety - Overhead distribution reduces the risk of electrocution compared with third rail.

The benefits arising from replacement of the 750V DC 3rd rail system with 25kV AC overhead may also be considered from the perspective of the various stakeholders:

- All parties will benefit from the reduction in sensitivity to ice and snow.
- Passengers will benefit from increased system performance, which can support reduced journey times and higher route capacity.
- Train operators will benefit from the reduction in energy consumption.
- Network Rail will benefit from reduction in the capital costs of renewal of the electrification infrastructure, from a reduction in the cost of track maintenance and renewal, and from reduced electrical distribution charges and costs of control.
- Taxpayers and passengers will benefit from reduced whole life system costs.
- Society in general will benefit from the reduction in carbon emissions associated with reduced energy consumption and from the reduction in risk of electrocution of members of the public who accidentally or deliberately stray onto the track.
- Additional benefits, considered too remote for evaluation in this study, include energy and operational cost savings from electric operation of freight and cross-country passenger services, and greater flexibility in cascading rolling stock

Conclusions

The conclusion of this research is that replacement of the 750V DC system with 25kV AC appears to be both feasible and economically desirable. The economic case is likely to improve as energy costs increase over time. The affordability of the change has yet to be determined, but an opportunity exists to start the replacement process within the next industry Control Period so that the advantage can be taken of the relatively large quantity of DC equipment becoming life expired at that time. To make such a change is a very significant decision to be taken by industry and government (as funder), and would require a large amount of further work to develop a whole industry business and

implementation plan to take account of the impact on train operators and the industry's customers.

Recommendations

The research recommends that the industry should prioritise the work needed to support the decision as to whether to include DC to AC conversion in the industry's investment agenda for future control periods. A fully developed business case will be needed, based on further evaluation and analysis. Finally, industry leaders should ensure that the stakeholder consultation process starts early through a cross-industry steering group.

Method

This research project has utilised a combination of industry stakeholders, internal RSSB resources and consultants to carry out the work, under RSSB's coordination. It represents a good example of a cross industry collaboration to address a complex systems issue.

Research project T633, *Study on further electrification of Britain's railway network* has contributed to this research by establishing a realistic method of estimating electrification costs and by underpinning the case for AC electrification on highly utilised routes.

The brief from the Future Electrification Group identified the options to be considered. These were reviewed during a stakeholder workshop and the general approach agreed. Two example routes (Basingstoke to Bournemouth/Weymouth and East Croydon to Preston Park) were identified. External (consultant) resources were used to carry out a detailed analysis of the costs and benefits of renewing the 750V DC equipment on these routes, and of converting them to 25kV AC. RSSB and stakeholder engineering resources were used to analyse the other options and to develop an outline economic case for the 25kV AC conversion of the whole DC network, using data from the example routes and from stakeholder sources, particularly Network Rail's current estimates for 25kV electrification of Great Western Main Line (GWML). The economic analysis used Department for Transport (DfT) guidance and valued the directly attributable financial benefits, including energy and maintenance cost savings and journey time reductions, plus the safety benefits assessed using the industry's standard value of preventing a fatality. DfT estimates for the impact on the economy of winter disruption were also factored into the case. Other potential benefits such as increased route capacity and electrification of

cross-country passenger and freight services were not included at this stage.

It must be emphasised that the figures developed in this study represent a high-level assessment of the likely balance of benefits and costs for railway electrical equipment. The estimates on which they are based are budgetary and are not intended to represent a full business case.

Deliverables

The research has delivered the summary report *Investigating the economics of the 3rd rail DC system compared to other electrification systems*, which includes the research findings, conclusions and recommendations. The report will be available to RSSB members upon request.

Next Steps

The research findings have been disseminated through the FEG, the V/TE SIC, the key stakeholders (Network Rail, ATOC, RIA and DfT) and to other interested groups and organisations within the industry.

Next steps have been suggested by the stakeholders involved in the research. The stakeholder group has recommended the establishment of a cross-industry steering group to develop a whole industry business case and a potential implementation plan to enable industry and funding leaders to decide whether to adopt the proposed plan.

The Technical Strategy Leadership Group has written to the Planning Oversight Group to incorporate the findings from the research into the industry's long term planning. The Rail Delivery Group (formed in response to the Rail VfM Study) has also decided to use the research project as one of its three case studies to see how the rail industry deals with strategic issues in future.

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