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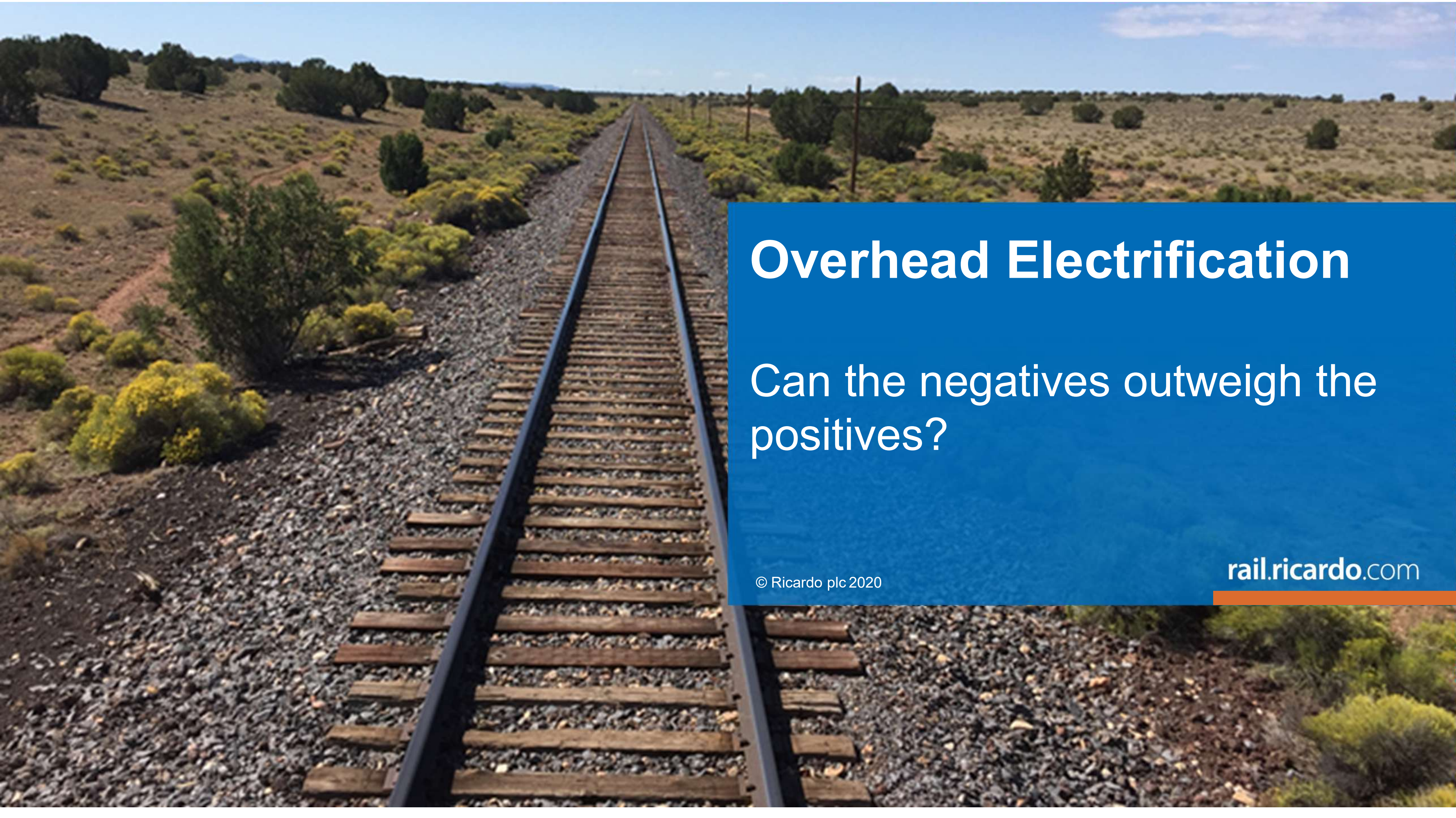

Overhead Electrification

Can the negatives outweigh the positives?

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Experts in critical and complex railway systems

We are rail industry specialists within the Ricardo group working to ensure that communities around the world are served by safe, resilient, high-performance railways.

Our expertise lies in understanding the complex and critical systems that underpin an efficient rail service, providing clients with skills and insight to navigate the sector's operational, commercial and regulatory demands.

Core service areas

- Systems engineering
- Asset optimisation
- Strategy and Planning
- Independent assurance
- Carbon reduction

Some of our global rail projects

Why a Google Earth view of this castle …? Listen on!

Introduction

Electrification, particularly overhead electrification at high voltage, is generally seen in a positive way.

Typical benefits claimed include the simplification (and thus reduction of cost) of rail vehicles, the local elimination of pollution, especially if the alternative is a diesel powered vehicle, and a cleaner image.

However, there are wider cost and external effects. These are not always fully thought through as an electrification scheme moves from the feasibility stage, through design and construction, to taking into use, and to the operations and maintenance phase.

Implementation Issues

Implementation Issues 1

Typically, physical implementation requires significant disruption to train services over months, if not years.

This can destroy the rail market on the route and thus, potentially, electrification's own business case.

For example, electrification of one commuter route required the suspension of evening and weekend services, forcing passengers to use alternative modes of transport. As the electrification works coincided with a recession, those other modes were not crowded and there was a degree of modal shift away from the railway that took a long time to recover.

Implementation Issues 2

Although it is now the practice to install signalling assets that are designed to be compatible with future 25kV overhead electrification, this was not necessarily the case in the past.

Therefore, where electrification does not coincide with resignalling, there can be a significant amount of work for the immunisation of the existing signalling, including, in particular, changes to track circuits.

Implementation Issues 3 - 1

The design life of a bridge is typically of the order of 100 - 120 years.

Some forms of bridge, such as brick and masonry arches, can, if the foundations are not disturbed, last much longer. When electrification requires the reconstruction of bridges, it has to be recognised that there is a cost in environmental terms of destroying bridges with decades of remaining life.

Implementation Issues 3 - 2

There does seem to be some potential for a former practice.

The London Brighton and South Coast Railway electrified much of its suburban service in the early years of the 20th century, using a 6.7kV AC overhead system. To avoid reconstructing certain bridges, there were “dead” lengths of contact wire.

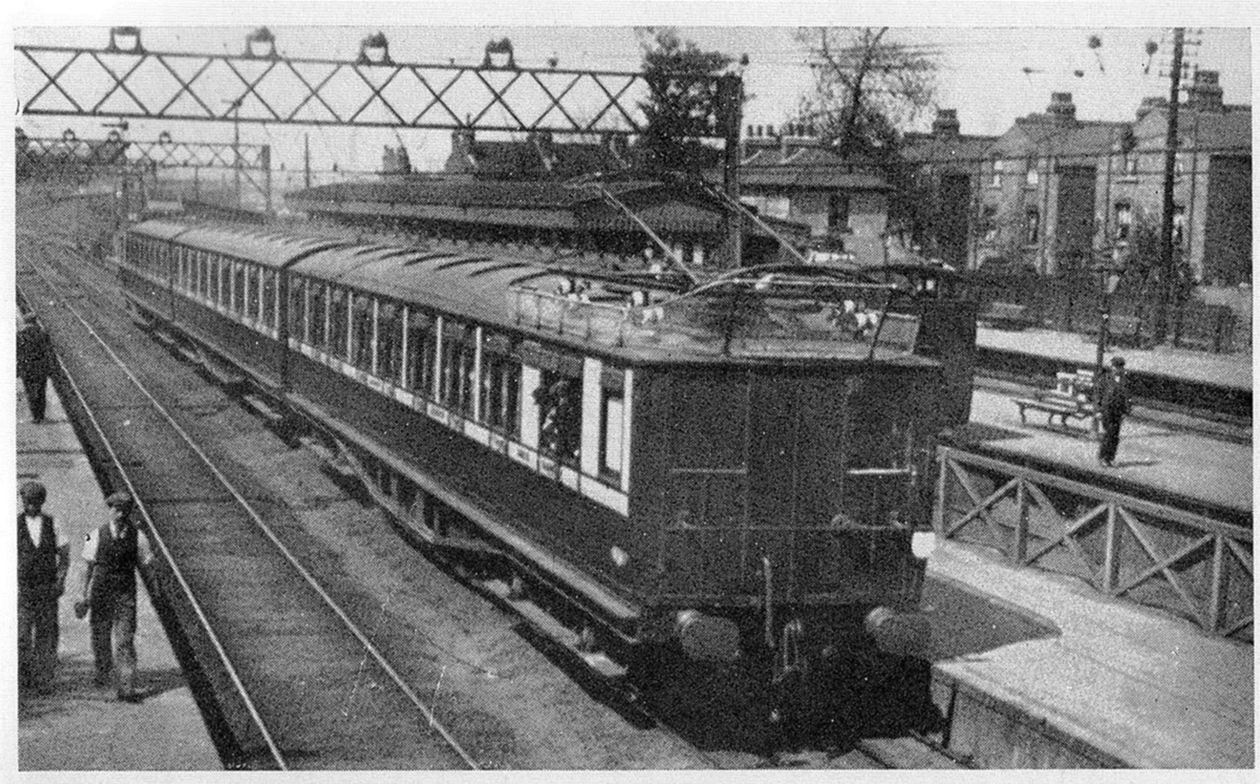
This concept is now being promoted as an innovation, although recent experience is still limited.

Implementation Issues 3 - 3

The trains could deal with quite a long dead section. Up to 60m is recorded in Hamilton Ellis's "The London Brighton and South Coast Railway"

Courtesy Wikipedia

Image on previous page in paper



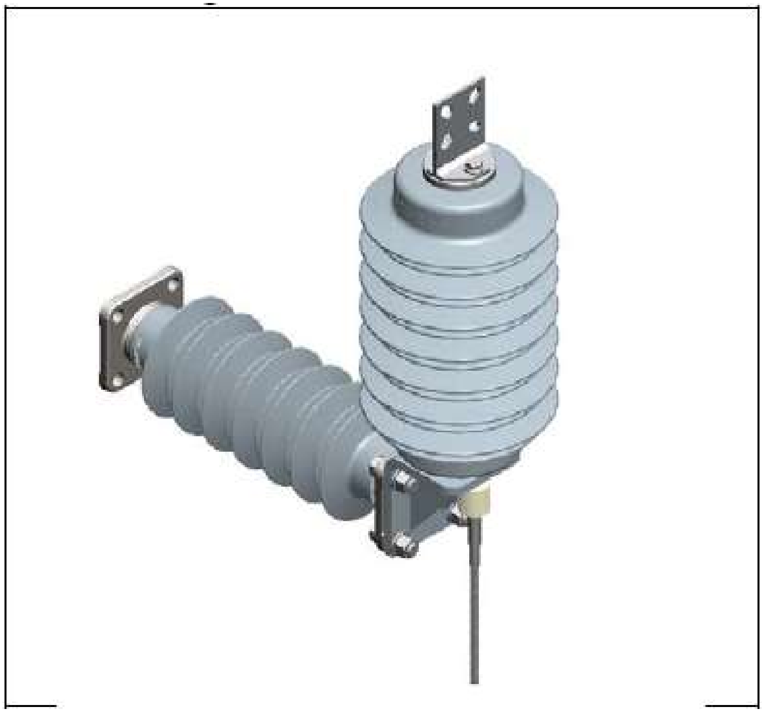
Implementation Issues 3 - 4

Great Western electrification introduced the concept of combining surge arrestors and insulating coatings at the Cardiff Intersection Bridges, avoiding difficult reconstructions.

It will be interesting to see how the coatings perform over the years and how often they have to be refreshed.

In that context, there is also a need to ensure that the insulating coating, or an equivalent, remains on the market.

Implementation Issues 3 - 5



Images of the GLS coating and NR accepted surge arrestor taken from material supplied to Ricardo Certification, the Assessment Body (in fact, me), in support of NR Safety Justification.

Implementation Issues 4 - 1

One alternative to bridge reconstruction is track lowering.

Where, as is often the case with older bridges, the abutment design relies on the presence of passive earth pressure on the lower face of the abutment for stability, the abutment needs to be underpinned. Unfortunately, there is usually also a need to modify the drainage, to avoid the creation of a sump.

Track lowering adversely affects the track top profile.

Implementation Issues 4 - 2

On a higher speed line, there is a need for long run-ins and run-outs, to comply with the relevant design parameters and to avoid the creation of a permanent speed restriction.

This work inevitably requires possessions longer than the maintenance "white periods" and, not infrequently, temporary speed restrictions whilst the new track profile is created.

As with bridges, there is a cost in environmental terms of changing an existing asset configuration with remaining life, generating ballast and track waste.

Implementation Issues 5

A second alternative to bridge reconstruction is the installation of a track slab, common where there is a tunnel or a succession of bridges.

It is rare that construction of slab track does not require a blockade of the track, for a period more likely to be measured in weeks rather than days. In addition, the construction of transitions between track slabs and ballasted track can be problematic in terms of quality control.

Implementation Issues 6

Electrification also requires a significant earthing and bonding exercise.

It is necessary to consider all existing metal structures, including footbridges, lineside fences, station furniture, etc. At metal bridges, the risk of dangerous touch potentials must be eliminated.

Increased need for on-site work

Increased need for on-site work 1

Whilst rolling stock can be maintained "off line" in warm, covered accommodation, protected from the weather, with plant, tools, support, etc., to hand, electrification assets have to be maintained at height, often at night and in the pouring rain, and, in winter, in the freezing cold.

This makes achieving quality difficult and introduces additional safety risks. If problems arise, support is remote.

Increased need for on-site work 2

Although train-mounted remote inspection techniques are now quite sophisticated, there remains a need for some physical inspection.

The same issues arise as for maintenance.

Increased need for on-site work 3

The need to use access platforms, whether train or plant based, means that there is a need for track access and, of course, for isolations of the electrification system.

Difficulties for other assets

Difficulties for other assets 1 - 1

Where the presence of electrification now means that track access for work also requires an electrical isolation, there is a significant reduction in available work time.

It is not the isolation itself that takes the time; this is merely a matter of switching. It is the need to secure against re-energisation and to apply earths.

Difficulties for other assets 1 - 2

There is a common misconception that the requirement to apply earths during an isolation is to deal with the possible presence of induced voltages due to adjacent live electrical equipment.

While it is true that such voltages do occur (and are sometimes remarkably high, in the thousands of volts), this is not the primary reason for the application of earths.

Difficulties for other assets 1 - 3

The primary function of the earths is to provide the security of the isolation from inadvertent re-energisation required by Regulation 13 of the Electricity At Work Regulations, SI1989/635.

Until the earths are applied, the overhead electrification equipment can only be said to have been “switched off” (in compliance with Regulation 12). The requirements of both Regulation 12 and Regulation 13 are absolute.

Difficulties for other assets 1 - 4

Use of risk assessments to support an “As Low As Reasonably Practicable” argument is not permitted.

Unless the switched off equipment is secured against inadvertent re-energisation, it cannot be said to be isolated and it would not be appropriate to issue any permit to work. It should be noted that the Regulations have not been made as a result of European safety legislation and that there are different electrical safety requirements in different European countries.

Difficulties for other assets 1 - 5

Permanent earths have been tried. They were used on the original British West Coast Main Line electrification in the 1960s.

However, many earths were used very rarely and became unreliable due to dirt, corrosion, etc.

It was found that a significant on-going effort was required to ensure that they were 100% effective.

Hence, the current practice of designated points to facilitate earth attachments.

Difficulties for other assets 1 - 6

I have had practical experience of these issues.

As a maintenance manager in the Birmingham area, I could contrast work on the electrified Rugby – Birmingham – Stafford lines with the non-electrified Derby – Birmingham – Bristol lines.

During my work as Implementation Strategist for West Coast Route Modernisation, I started to review the post-modernisation inspection and maintenance workload for each asset and assess whether the track access was sufficient.

Difficulties for other assets 1 - 7

It was a factor in my work for High Speed 1 Control Period 2 track access charge submission.

I had to explain to the Regulatory hearing the relationship of cost, available work time and quality for the inspection and maintenance work.

Hours of operation are much longer than on French Lignes à Grande Vitesse, as the Javelin service starts early and finishes late, and there may be some limited freight traffic.

There is also no daytime “white” period.

Difficulties for other assets 1 - 8

Worked (far from extreme) example:

Assume “white” / no trains period is 4 hours

- Apply earths – 0.5 hours (probably longer)
- Mobilise on site after permit – 0.5 hours
- Work – 2 hours
- Clear site, surrender permit – 0.5 hours
- Remove earths – 0.5 hours (probably longer)

Longer sites require earths at least every 400m.

Difficulties for other assets 1 - 9

Second worked example:

Assume “white” / no trains period is 4 hours

- Mobilise on site – 0.5 hours
- Work – 3 hours
- Clear site – 0.5 hours

Absence of OLE increases effective time by 50%

Difficulties for other assets 1- 10

Also an issue, but perhaps less so, for conductor rail electrification.

The Electricity at Work Regulations led to much greater use of short circuiting straps, but these are easier to attach than OLE earths.

Many OLE routes are mixed traffic and without electrified diversionary routes. Conductor rail track is often on commuter routes or multi-track main lines, many with electrified diversions. Extensions to “white” periods are easier to agree.

Difficulties for other assets 2

As noted earlier, the overhead electrification asset requires track access for inspection and maintenance activities.

This means that, for those wishing to carry out maintenance and inspection work on other assets, including track, signalling and structures, there is an increase in competition for track access to carry out that work.

Difficulties for other assets 3 - 1

Where a line is electrified on the overhead system, track must be maintained to tighter tolerances.

This is particularly important for cross-level, as the effects at track level are typically multiplied three times at contact wire level. Care must also be taken over the maintenance of top - to avoid affecting contact wire gradients - and of alignment.

Difficulties for other assets 3 - 2

On straight track, the contact wire is arranged in a zig-zag pattern, to minimise the risk of wearing a groove in the pantograph contact strip.

On curves, the contact wire takes the form of a series of straights.

In both situations, the track alignment must be managed to ensure that the pantograph remains in contact with the contact wire.

Difficulties for other assets 3 - 3

This need to maintain to higher tolerances means that track access for maintenance is required more frequently than would otherwise have been the case.

On high speed lines, the need for precise management of track cross-level, top and alignment usually means that the presence of overhead electrification is less of an issue.

Difficulties for other assets 4

As the rails are used as the initial return for the traction current, great care must be taken when carrying out work not to interfere with the path. The "red bonds" which are part of the link between the rails and the return conductors can, in some fault conditions, be live at 25kV. Extension of electrification increases the presence of bonds. This is in contrast to signalling, where the increasing use of axle counters reduces the number of bonds attached to the rails.

Difficulties for other assets 5

The need to maintain 3.5m clearances to live overhead line electrification equipment (not just the contact wire) complicates the maintenance and cleaning of station structures, particularly platform canopies.

Difficulties for other assets 6

Where the introduction of overhead electrification has meant the installation of sections of slab track, e.g., through tunnels or under a succession of bridges, there is a need for transitions between the track slabs and the ballasted track at either end.

Because of the varying degree of rigid support, the transition is difficult to maintain, with additional attention (and thus requirement for track access) having to be paid to cross-level and top.

Difficulties for other assets 7

There is a need for additional vegetation management, particularly where there is a risk of tree branch contact with unsheathed return conductors, requiring further additional track access and isolations.

Single point of failure

Single point of failure 1

Overhead electrification introduces a new failure mechanism for the railway, in that a loss of power immobilises the train, whatever the state of the non-electrification engineering assets.

Accordingly, many suggestions for mitigating electrification failure consider how power can be brought to the train. However, a failure of the mechanical electrification system is unlike the other engineering assets; there is essentially a single point of failure which cannot readily be mitigated to allow trains to pass and clear the line.

Single point of failure 2

Concern about this type of failure with a transmitted power system goes back to the earliest days of the railways, and the debate amongst the proposers of the Liverpool & Manchester Railway about whether cable haulage or locomotive haulage was the way forward.

Similar discussions of principle surrounded the atmospheric system.

Single point of failure 3

In many situations, a failure of the catenary system or a headspan means that the clearance required to pass trains is infringed.

This affects non-electrically powered trains as much as electrically powered trains, although the non-electrically powered do have hotel power whilst waiting for the situation to be resolved.

Single point of failure 4

Objects blown on to the railway obviously cause the suspension of train services whilst they are removed.

However, where the line is electrified, there is an additional likelihood that, for example, plastic sheets will be caught - and then an additional problem in that the removal requires the electrification to be isolated and made safe before the object can be removed, increasing the time required significantly.

Managed degradation

Managed degradation 1

In contrast, failures of other assets are often amenable to mitigation which will allow the movement of self-propelled trains, so reducing the disruption to passengers and freight customers.

Managed degradation 2

If a broken rail is reported, then processes are in place, e.g., clamping, which will, in many situations, allow trains to be passed.

This may possibly mean the train moving at walking pace and with inspection required after every movement over the break, but at least movement is possible.

Managed degradation 3

Similarly, a developing track cross level twist or a subsidence can be dealt with by packing the track between trains and, as necessary, allowing movements at walking pace.

However, this may not be possible where there is overhead electrification because of the need to maintain the pantograph / contact wire interface within tolerance.

Managed degradation 4

When the track has buckled, it is possible, if space is available, to slue the track to form reverse curves that will allow movements at slow speed.

However, this may not be possible where there is overhead electrification because of the need to maintain the pantograph / contact wire interface within tolerance.

Managed degradation 5

Where an underbridge has been struck by a road vehicle, processes are in place which can, subject to conditions, often allow movement at walking pace pending structural examination.

Managed degradation 6

Points can fail for many reasons, but it is normally possible for them to be operated manually by staff on site, in accordance with the signaller's directions, to permit trains to pass.

Managed degradation 7

When the control system fails, various mitigation measures can be introduced, depending on the nature of the failure.

Movements may be authorised through a section at caution, or "station-to-station" working may be introduced. If the failure is likely to remain for an extended period, "ticket" working may be practicable. If the signalling fails on a single line, pilot working is introduced, in which a clearly identified person effectively acts as a human staff.

Conclusions

Whilst the introduction of overhead electrification may have benefits for the operation of the system and for its users, it must never be forgotten that there are significant operational and asset management disbenefits.

These must be carefully considered as part of the commercial analysis of electrification proposals.

Environmental alternatives

- Hydrogen engines, can use modified diesel engines … *but fuel tank capacity to meet heavy freight loco range requires tenders…*
- Hydrogen fuel cells
- Batteries
- Liquid air
- Liquefied Natural Gas, as an interim?

Not an alternative

Courtesy YouTube

Courtesy Rail UK/Rail Media

Ricardo carried out some work on hydrogen for freight early in 2021. Hydrogen is not high energy fuel. The initial thought was something the size of a brake tender, but calculations showed the tank on the right was not enough for current ranges.

Issues with alternatives 1

Courtesy YouTube

Courtesy Rail UK/Rail Media

The left hand photo is Florida East Coast, the right hand photo is Russia. What they both have in common is Liquefied Natural Gas as a fuel … and increased length affecting run-rounds, etc.

Issues with alternatives 2

Courtesy Google Earth and portstrategy.com

Issues with alternatives 3

Supply of hydrogen

- Train operators in Germany withdrawing hydrogen powered trains due to difficulties in maintaining adequate supply (source Modern Railways Feb 2025)

- Bus operators in England refused permission for hydrogen storage as, for a fleet of 97 buses, the 5 tonne facility required is a COMAH site and HSE advised against granting consent (source CILT Focus; June 2024)

Non-environmental alternative!

Diesel under OLE all the way, 226 miles

10 August 2019 | **16 November 2019**

Google Streetview of my route after OLE issues