A word about freight

- Taking a wide economic view of decarbonisation, reducing the volume of HGVs on the road is a priority
- Modal shift from road to rail of long-haul container traffic from the ports to the inland distribution terminals should be a national priority:
- Relatively modest gauge clearance improvements will facilitate that modal shift with diesel locomotives
- That will be a major contribution to UK decarbonisation
- Electric haulage of that traffic will need some new electrification

Strategic Electrification for Freight

- Whilst the class 99 is a tri-mode locomotive:
  - Under diesel power and heavily laden acceleration and speed are constrained
  - Battery power is useful, but only for “last mile” and movements in terminals
- Civil structures which need gauge clearance for containers should always be provided with space for continuous live OLE clearance
- Very short discontinuities may in some circumstances, be suitable for class 99 to pass under diesel power
- Where lower speed of the train is not a capacity issue, class 99 diesel operation is practical
- Discontinuous electrification on main lines is unsuitable for freight

The case for electrification

- EMU trains powered by fixed continuous contact systems are:
- Faster
- More powerful
- Lighter
- More energy efficient
- Quieter
- Emissions free
- Less complex
- More reliable

Arguments made against **continuous contact systems**

- Long period of disruption due to access for construction of enabling works
- Electrification is too expensive
- Extremely bad record of uncontrolled costs *(to be clear I must concur that the CP5 record was shameful)*
- Modern traction alternatives (batteries) deliver the same benefits without need of a continuous contact system
- Other improvements such as ETCS are far more deserving for available capital investment funding, increased capacity beats traction change

Rail electrification considering the UK economy

- The CP5 poor investment performance, most particularly GWEP, was disastrous
- UK economic problems: a compound of the effect of BREXIT and
- Damage done by self-inflicted economic “road crashes” by a series of governments
- HS2 will have the “lions share” of national transport investment funding for the next 10 years

Failings on Great Western upgrade raise concerns over future rail projects

3 March 2017

The Public Accounts Committee report say that the Government must learn from serious failings in the design, planning and cost-estimating of the Great Western route modernisation programme.

Electrification history repeats, over and over again

- Every generation has faced their own version of these challenges
- Caught in your time it can seem it has never been this hard
- This generation is in the slump side of the curve now
- The rush to adopt alternative and novel traction forms is a particular feature of the here and now, but the long view of history almost always reveals that nothing is completely new

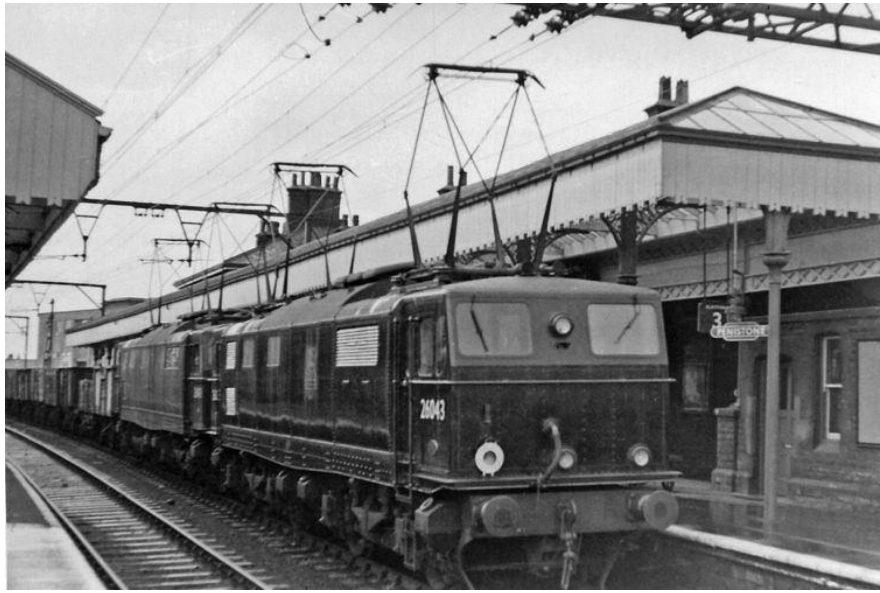
The 1955 Modernisation plan

- The 1950s modernisation plan included a rolling programme of network wide electrification across the years to 2000

- The need to keep the railway going gave life to the last generation of steam locomotives, the magnificent class 9F

The Modernisation plan electrification

- By the 1980s the flag ship of that programme, the MSW could not survive
- But the experience and knowledge gained helped shape all that followed



- Funding dwindled; the train builders pushed dieselisation as the panacea as an alternative replacement for steam, avoiding electrification and delivering much quicker

The Modernisation plan dieselisation

- A large variety of diesel types were purchased
- Some of those variants were expensive failures, many were scraped

- Batteryisation?

- It feels to me that we are in danger of an updated repeat as we race towards a multiplicity of BEMUs for the same reasons

The funders perspective in the here and now

- Primarily the railway is victim of its own immense self harm
- Delivery of electrification in CP5 failed, and failed spectacularly
- HM Treasury is opposed to the cost and risk of rail electrification
- Failure to move away from the CP5 delivery model **consolidates** the funder's view
- Planning and cost estimates based on CP5 simply confirm Treasury views that:

Full electrification is unaffordable

Other forms of traction gain increased support

- The oil industry is not dead, Donald Trump is champion (diesel fight back)
  - The influence of “big oil” is significant and well funded
  - The success of this is evident, COP 30 failed to mention elimination of fossil fuels
  - This makes the adoption of diesel bi-modes seem like the acceptable and even responsible base case

- Batteries have been proven in cars, vans and buses but
  - Operational life of batteries in trains is not yet certain, the technology is not mature
  - No practical battery long-haul HGV is possible, nor foreseeably so
  - For rail applications, power and energy capacities place high speed passenger and freight heavy haul beyond the compass of battery technology

- Caught between moving towards net-zero carbon, and unaffordable electrification, discontinuous electrification as a concept has gained momentum

The BIG PICTURE

- Full continuous electrification is the best solution, that is beyond dispute, but:
- There is no money, electrification is a long way down the list of works competing for Treasury investment funding
- NR estimates and plans continue to use CP5 costs, the BCR is unsupportable
- Even if Treasury investment funds were available, there are more deserving and better value for money projects higher up the list
- NOTE WELL: THIS IS THE MAIN MOTIVATION PUSHING ELECTRIC TRACTION WITHOUT BUILDING A FIXED CONTACT SYSTEM

Perceptions

- Battery bi-mode electric trains look like an “off the shelf” product
- BEMUs are snatched at as **THE** solution
- Diesel bi-mode operation always stands as the backstop solution
- This allows discontinuous electrification to be presented as affordable and low risk
- Decarbonisation can be achieved runs the argument, by this innovative new form of electrification without the cost and disruption of the “unwanted” continuous contact system

Four forms of discontinuous electrification

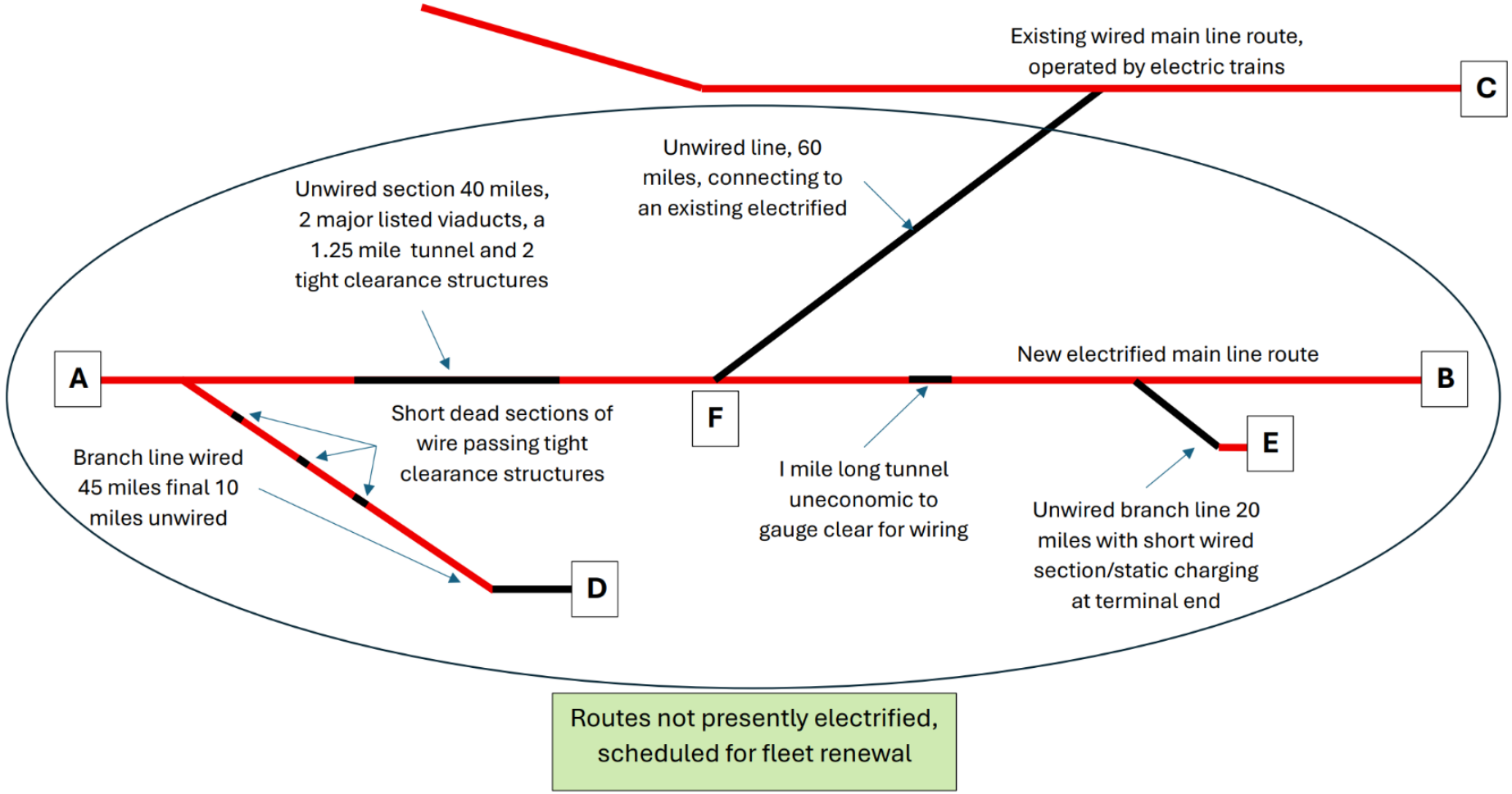
1. Continuous electrification with non electrified branch lines/sidings

2. New electrification with short gaps to pass discrete features such as low bridges and restricted tunnels using bi-mode trains

3. New electrification with gaps with no wire for long distances operated using bi-mode electrics

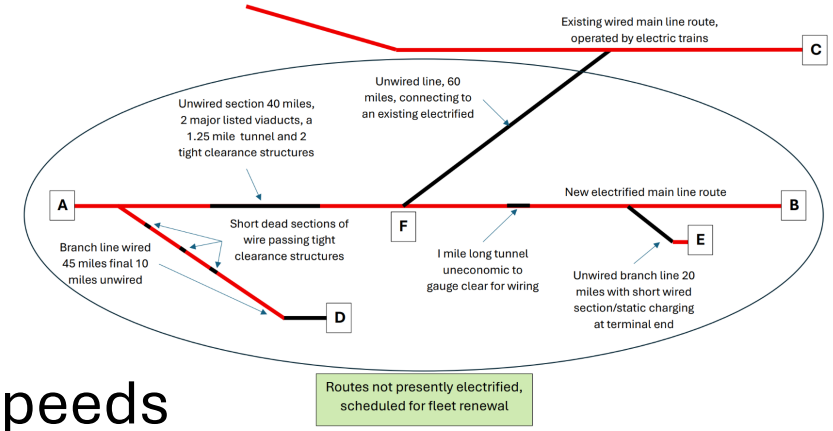
4. Static charging facilities without a running line contact system

A hypothetical main route, and branches with unwired sections



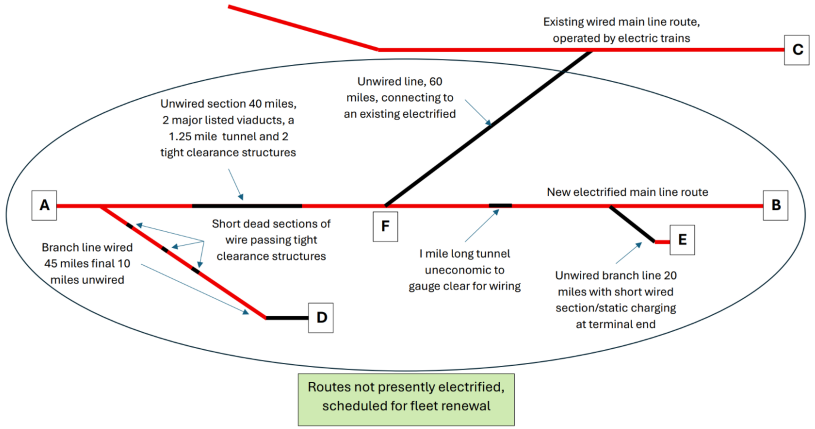
- Service A-B
  - Diesel bi-mode
- Service A-C
  - Diesel bi-mode
- Service A-D
  - Battery bi-mode
- Service A-E
  - Diesel bi-mode
- Service F-E
  - Battery bi-mode

The fleets required for that scheme



- Diesel bi-mode (DEMU)
  - Diesel engines must match power requirement for line speeds
  - NB. diesel bi-modes could of course operate all service groups
- Battery bi-mode (BEMU) for service A-D
  - Battery duty passing tight clearance bridges is very light
  - Battery duty for 20 miles return turnaround is more demanding but practical
  - Batteries should be able to charge from OLE, no static charging required
- BEMU for service F-E
  - Battery duty comparable to that for the A-D service, a common fleet is possible
  - There is however no usable route for battery trains to get between A-F on the main line, so 2 separate and independent fleets needed
- Existing electric trains operating on the other existing route could never work services C-A

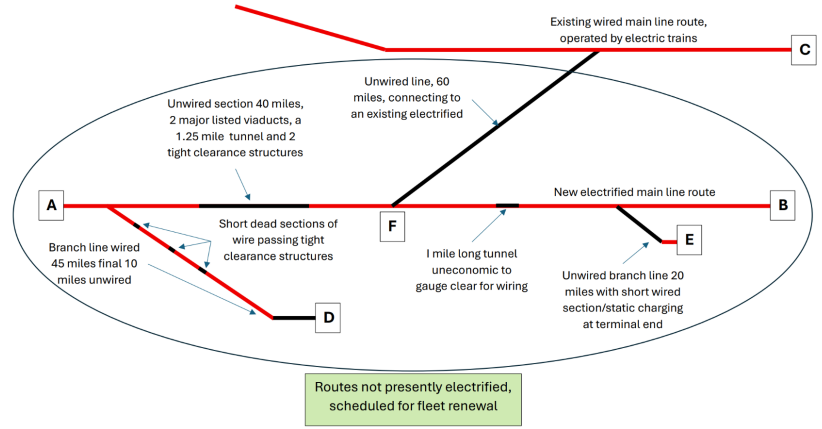
The benefits



- The scheme has avoided:
  - Around 250 single track kilometres of wiring
  - Demolition and reconstruction of 5 bridges
  - Extensive and complex civil engineering to gauge clear 2.25 miles of tunnels
  - Difficult, troublesome and lengthy listed structure planning consent submissions
  - Difficult construction work to fit OLE structures on significant heritage viaducts
- That would deliver considerable cost and time savings

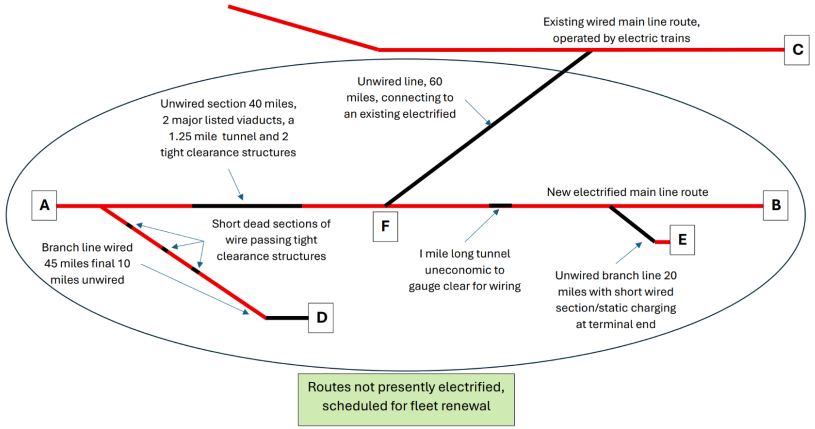
- But nothing in life comes for free

Costs for the train fleet



- Bi-mode trains are more complex and higher capital cost
- Maintenance, particularly for diesel engines, increases OPEX and reduces reliability
- Whole life cost of batteries will include periodic battery renewal
- Depot facilities for battery and diesel bi-modes are more involved
- Stabling sidings and depot roads may require fixed charging supplies
- Expensive firewall protected storage for batteries is essential
- The fleet will be more expensive to buy
- The fleet will be more expensive to operate
- BEMUs will have limited flexibility to operate on other parts of the national network

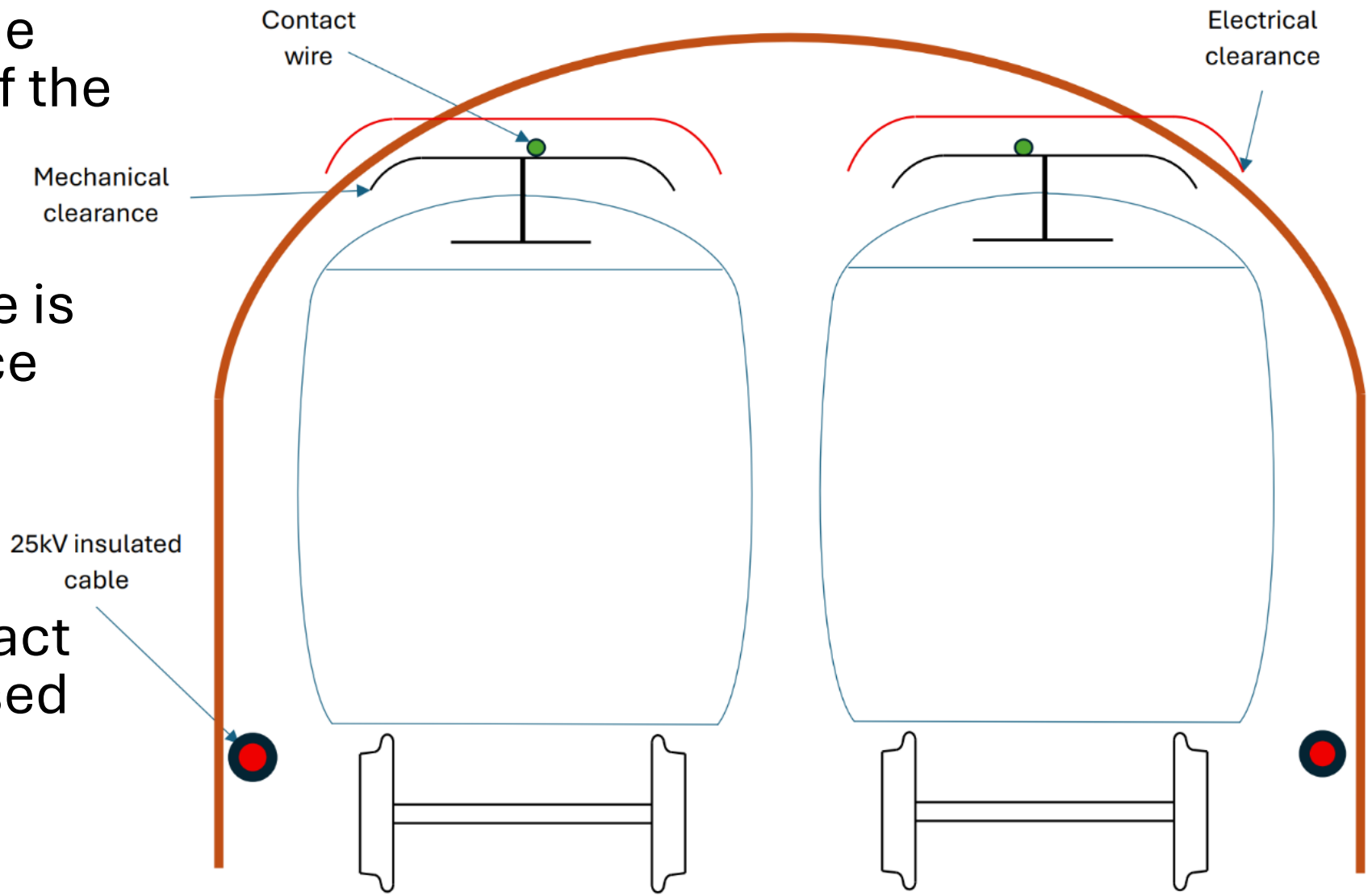
Costs on the infrastructure



- Automatic Power Change Over at 14 sites
- Fixed charging facilities at E
- Extra bay platform at Junction F
- Loss of N-2 along the A end of the main route (I will come to that)
- Heavy battery charging load for trains on the line from A to D
- 25kV cable installations passing the discontinuous sections on the route to D and at the tunnel between F-B
- Additional train maintenance depot facilities to allow for the separate operation of two independent islands of BEMU fleets
- Potentially power supply upgrade on the existing electrified route

Mechanical and electrical clearance

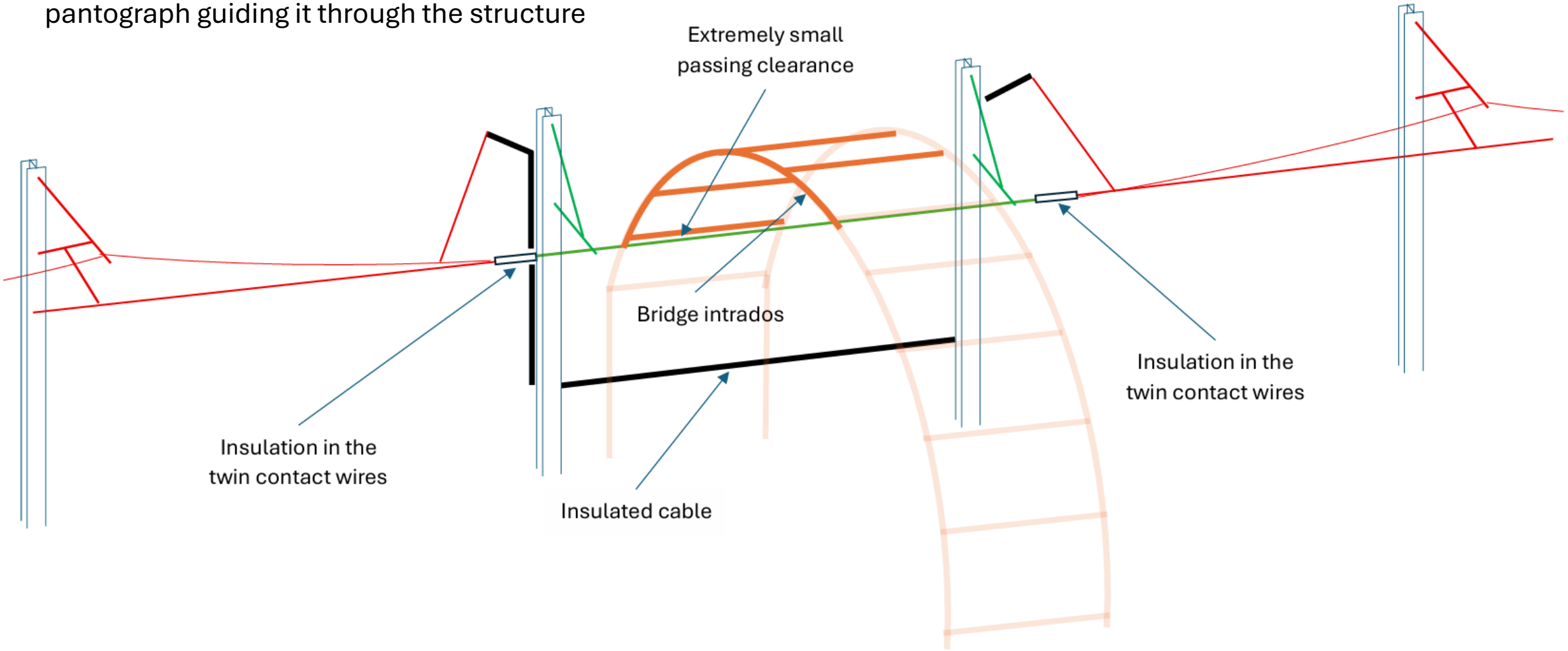
- Black pantograph is the physical description of the pantograph
- Red pantograph profile is the electrical clearance needed
- This illustrates how electrically dead contact wire can guide the raised pantograph through a bridge



Discontinuity at a bridge

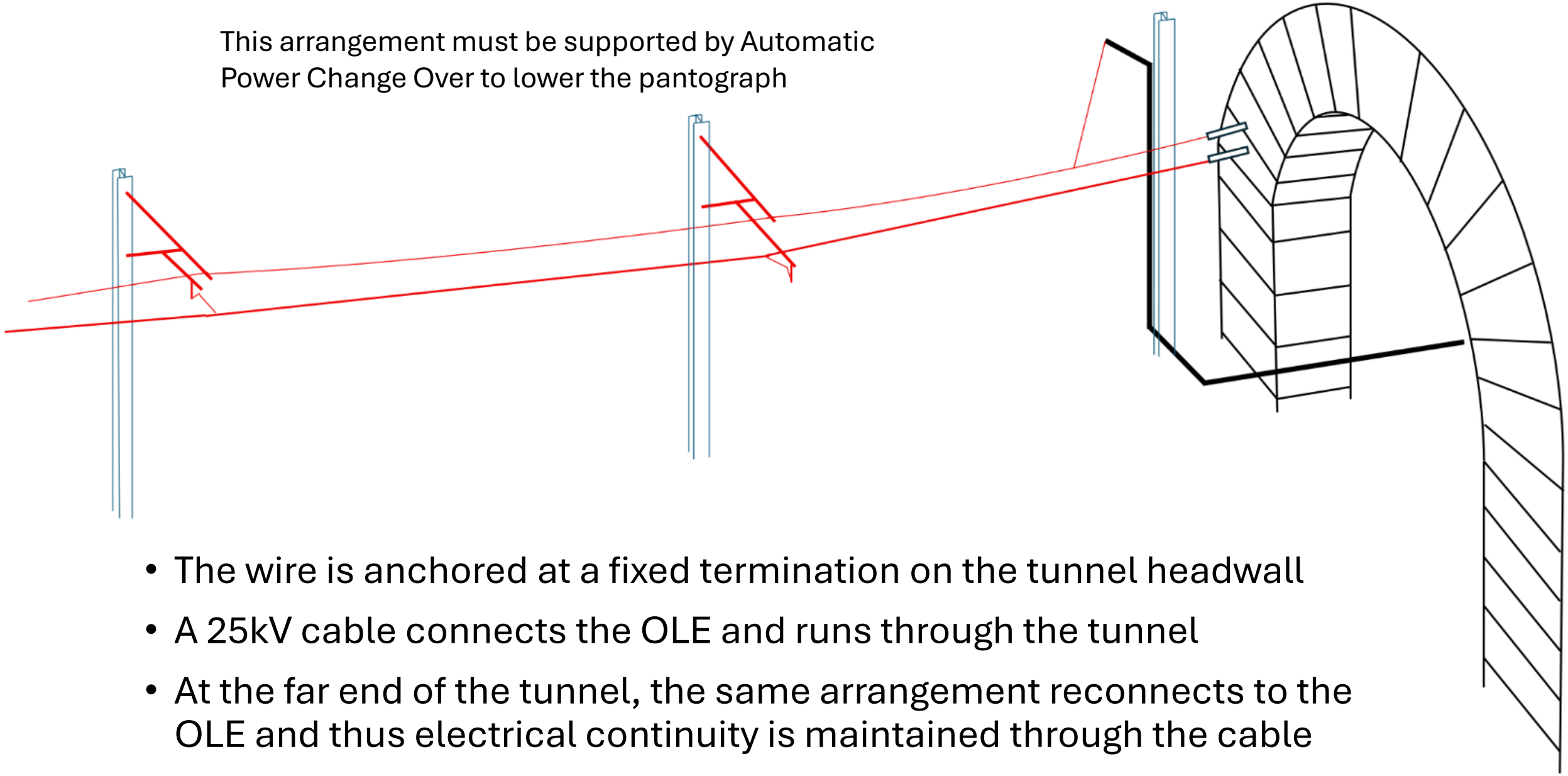
- The OLE is electrically dead under the bridge, but mechanically remains in contact with the pantograph guiding it through the structure

- This arrangement must be supported by Automatic Power Control to disconnect the train from taking electrical current as it crosses the inline insulation



Discontinuity at a tunnel

This arrangement must be supported by Automatic Power Change Over to lower the pantograph



- The wire is anchored at a fixed termination on the tunnel headwall
- A 25kV cable connects the OLE and runs through the tunnel
- At the far end of the tunnel, the same arrangement reconnects to the OLE and thus electrical continuity is maintained through the cable

What is N-2 feeding, and why does it matter?

- Traction supplies derived from the high voltage grid are very reliable, but they can, and do occasionally fail, or must be switched off for GRID maintenance

- Each Feeder Station (FS) is engineered with parallel redundancy, either of two transformers can support the whole load connected to that FS

- When both feeds to a FS fail, the adjacent FS can provide supply under extended feeding

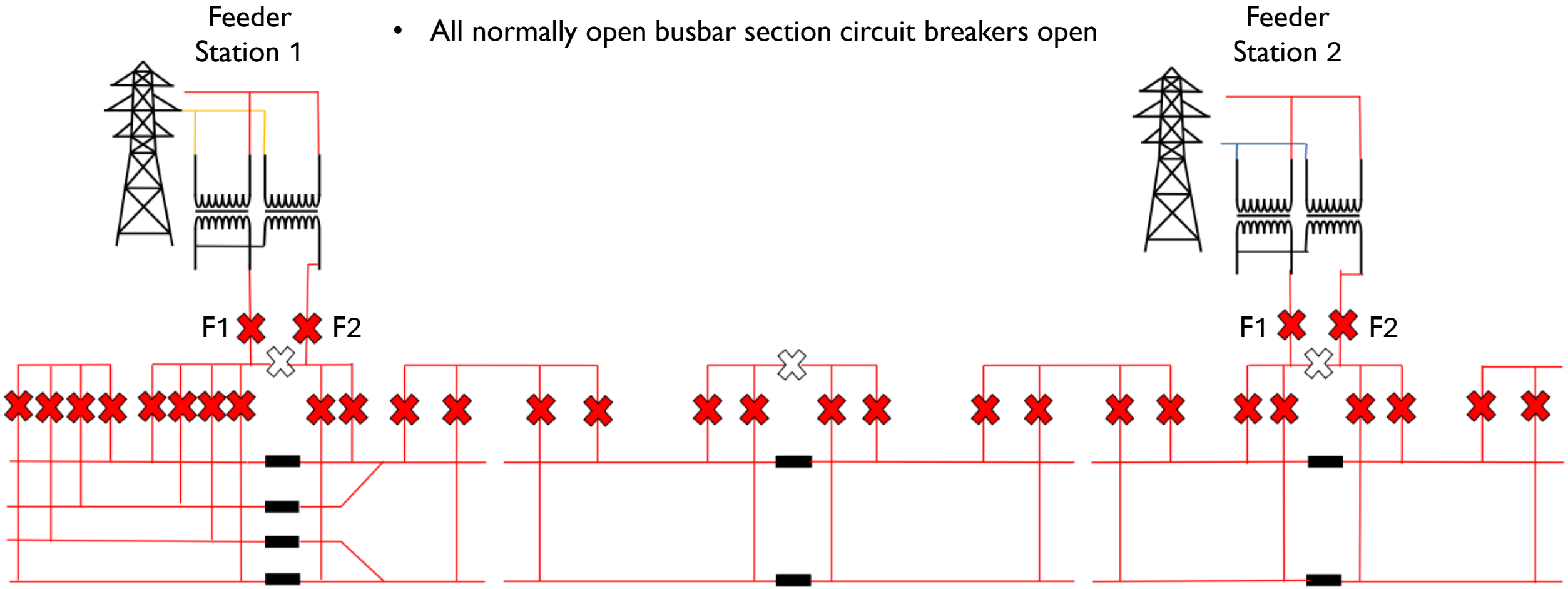
    - With all supplies live, the system is said to be normal feeding “N”
    - When a single transformer supply fails this is “N-1”
    - When both circuits at the same FS fail this is “N-2”

Traction Supply Normal "N"

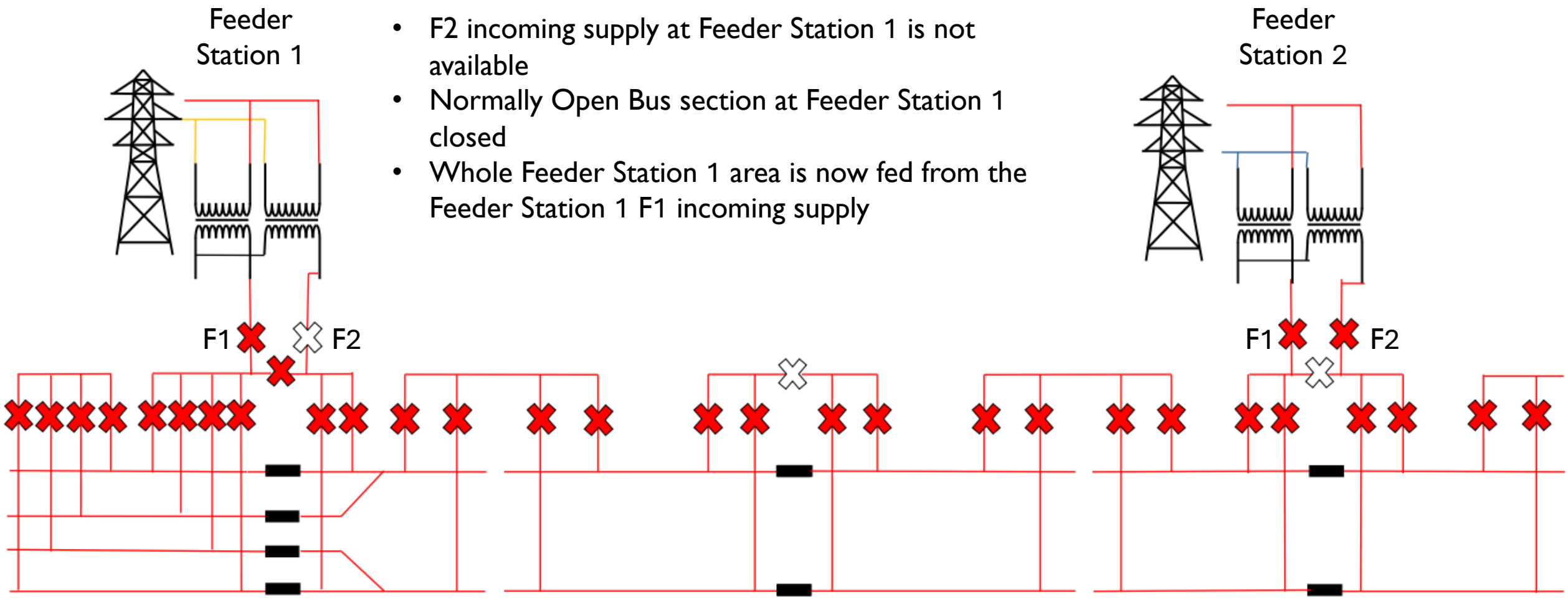
Closed circuit breaker

Open circuit breaker

- All incoming supplies live
- All normally open busbar section circuit breakers open



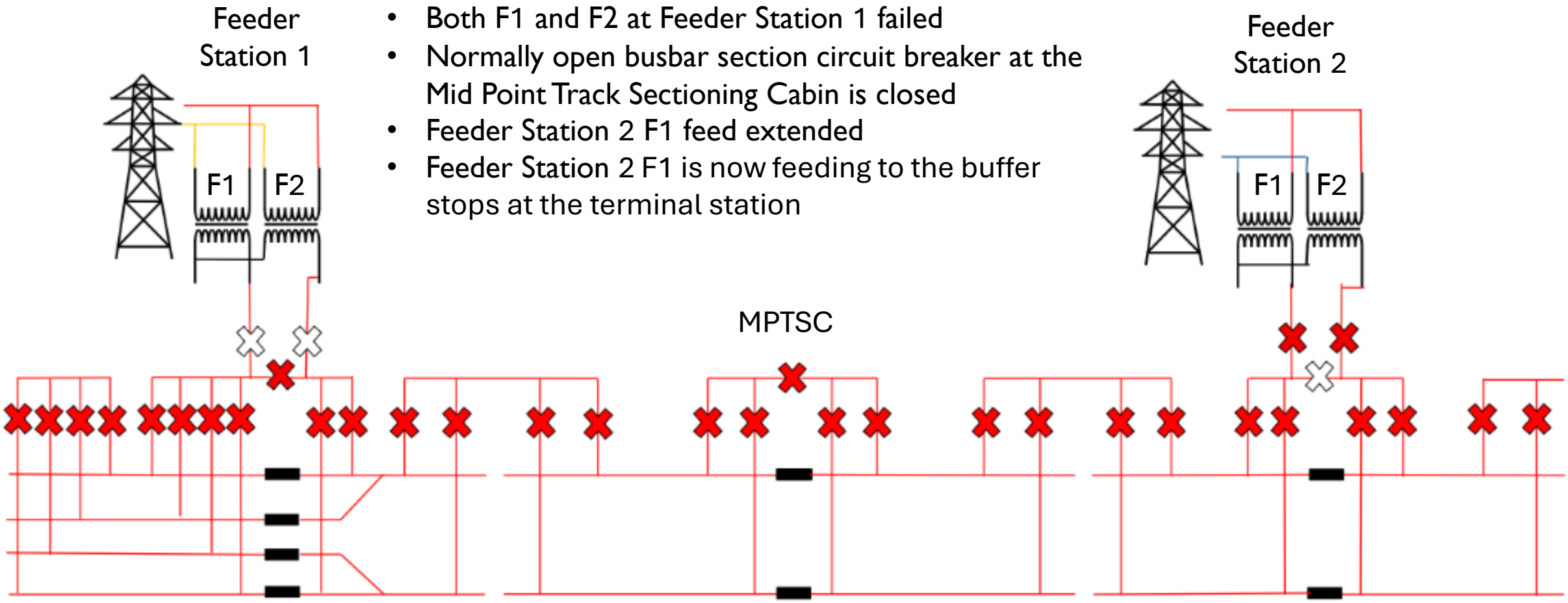
Traction Supply
First Emergency Feeding "N-1"



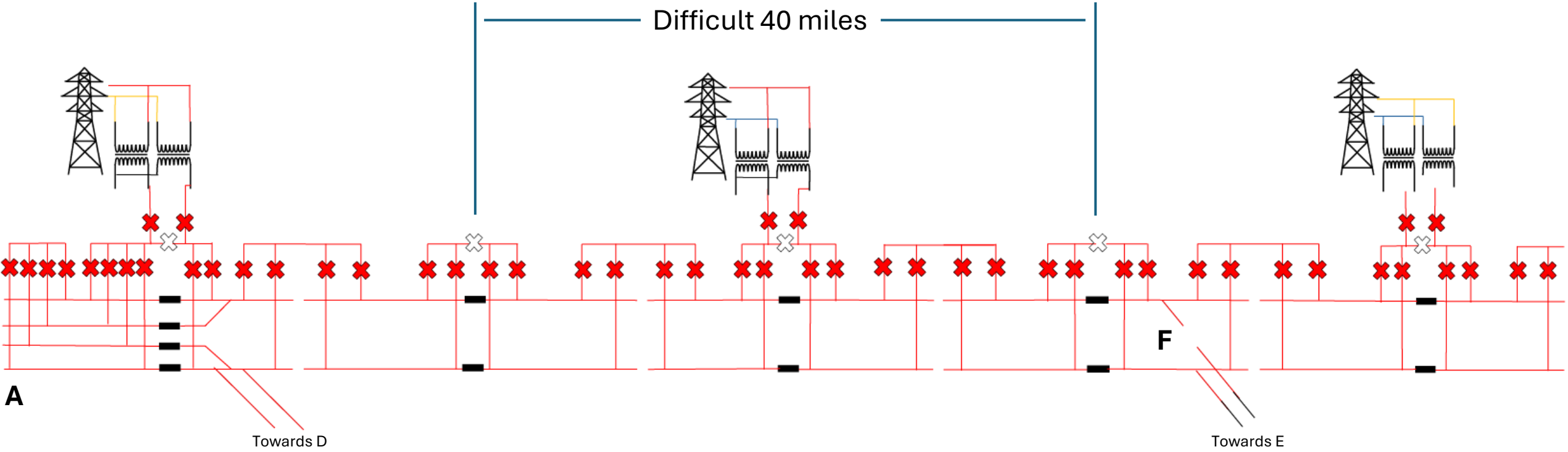
- F2 incoming supply at Feeder Station 1 is not available
- Normally Open Bus section at Feeder Station 1 closed
- Whole Feeder Station 1 area is now fed from the Feeder Station 1 F1 incoming supply

Traction supply
Second Emergency Feeding “N-2”

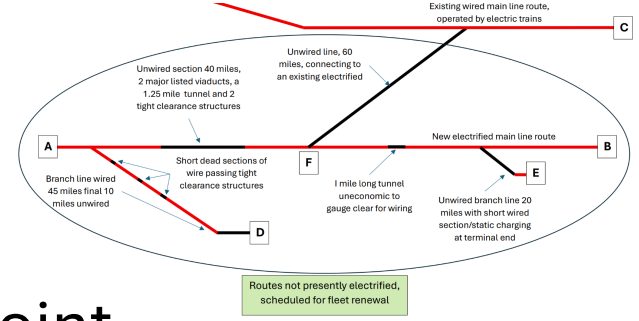
- Both F1 and F2 at Feeder Station 1 failed
- Normally open busbar section circuit breaker at the Mid Point Track Sectioning Cabin is closed
- Feeder Station 2 F1 feed extended
- Feeder Station 2 F1 is now feeding to the buffer stops at the terminal station



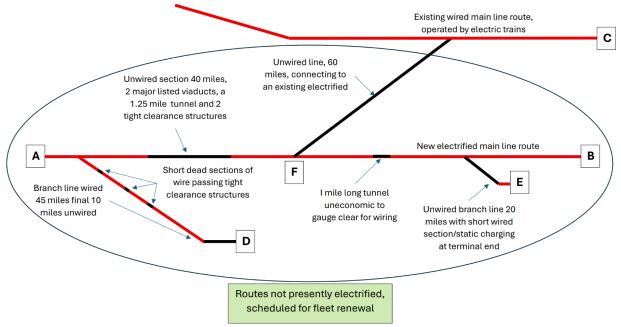
25kV classic continuous feeding (A-F on my fictitious railway)

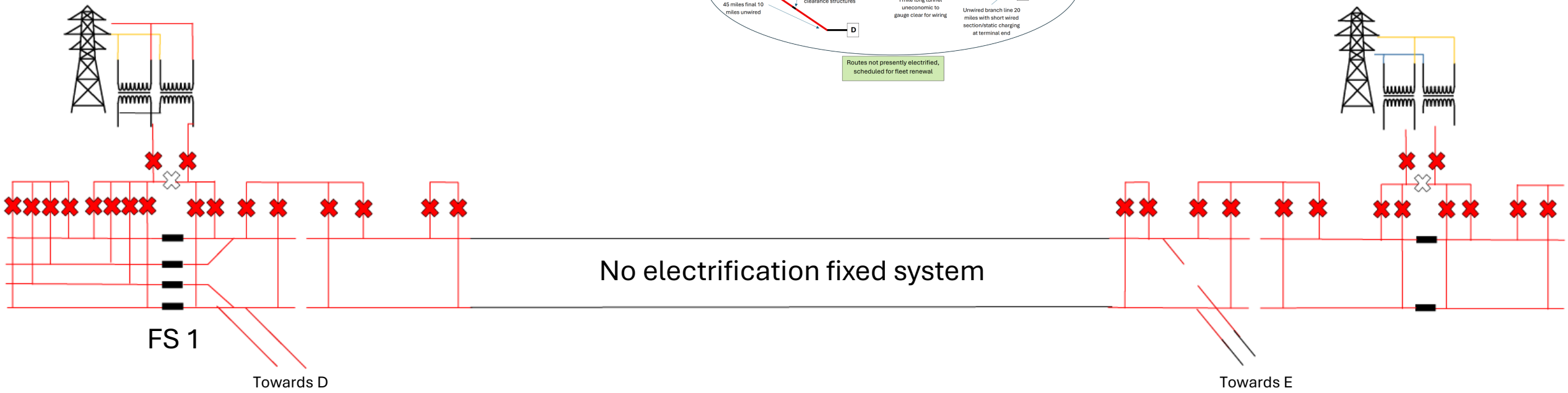


- 3 traction supply points (6 traction supplies)
- Approximately 385 single track kilometres of OLE
- Resilient against single traction supply failure
- Operable with twin supply failure at any single supply point



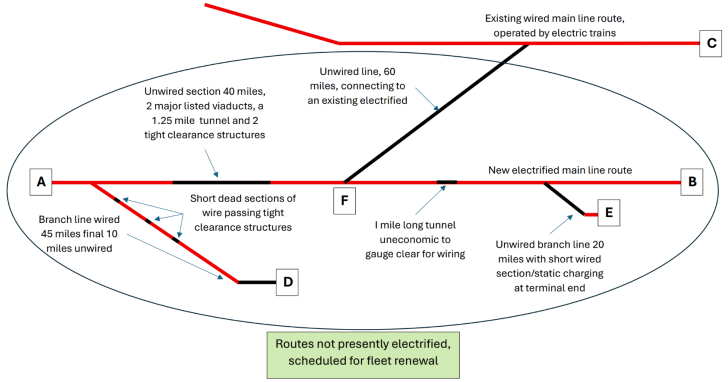
The 40 miles gap





- 2 traction supply points (4 traction supplies)
- Approximately 255 single track kilometres of OLE
- Resilient against single traction supply failure
- NOT OPERABLE with twin supply failure at FS1 supply point
- Loading on traction supplies around 1.5 to 2 times greater to charge batteries on route to D

Battery charging



- There are several ways of charging train batteries:
  - From the OLE on the move
  - From the OLE when stationary
  - From a fixed battery charging supply when stationary, either by a plug and cable, from a short section of contact system above the stationary position of the pantograph or from a conductor rail in the four foot
- Fixed battery chargers need to deliver the equivalent of N-1/N-2 reliability
- Feeder Stations with BEMU trains in section must have sufficient capacity to power all the trains operated on the route and charge the BEMU batteries
- Thermal effects of charging current may require reinforcement of the OLE
- This can drive the need for traction supplies which may be between 50% to 100% larger than would be the case for pure EMU operation

In summary

- The application of some discontinuous electrification is eminently sensible BUT:
- Discontinuous electrification is useful only if it delivers a whole life economic solution for the railway, **never ignoring freight**
- If compromised resilience is genuinely all that can be funded, then adopt that solution with eyes open, don’t pretend it is a direct equivalent of full electrification
- Whatever form of traction is chosen, it should deliver to wider society the most reliable, resilient and environmentally and economically sustainable solution that can be afforded
- Where discontinuous electrification compromises are accepted, there should always be an intent to close gaps and improve resilience in the longer term, sub-optimal engineering should not become normalised

The case for and against discontinuous electrification

- There is no funding for full electrification
- There is appetite (and legal obligation) to minimise diesel traction by 2050
- To make that work the railway needs some new fixed electrical systems and upgrades
- Anything that moves away from fossil fuel is good
- On that basis discontinuous electrification meets the need of our time

- There is an element of wishful thinking bordering on naivety
- Exaggerated benefits are being claimed
- Evidence shows projects will revert to diesel bi-mode trains
- Compromised, less resilient fixed installations (loss of N-2) become normalised
- There is insufficient debate to secure understanding that discontinuous schemes are a staging post towards a goal, over time, for full electrification