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Guidance Note

Overview of Electromagnetic Coupling Between Traction Systems and Telecommunications Cables

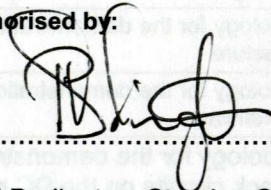
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Reference documentation

BR 13422	50 Hz single phase AC electrification. Immunisation of signalling and telecommunications systems against electrical interference.
NR/L2/TEL/31107	Limits and test method of induced voltages on telecommunications cables due to electrification systems
NR/SP/TEL/31001	Operational telecommunications – Maintenance testing and failure investigation process (TMT & FIP)
NR/WI/TEL/30070	Maintenance of telecoms copper cables
NR/SP/TEL/21085	Specification for the design of earthing and bonding systems for 25 kV AC electrified lines
NR/GN/ELP/24015	Guidance for the technical management of booster transformer outages
NR/SP/ELP/24011	Booster transformer outages
NR/GN/ELP/27010	Guidance for compatibility between electric trains and electrification systems
NR/SP/TEL/30036	Booster transformers outages: Managing the consequences for telecommunication systems
NR/SP/TEL/30003	Immunity test requirements for lineside communications systems
NR/PS/TEL/31102	Screening conductor for the immunisation of telecommunications cables
NR/SP/SIG/50001	Methodology for the demonstration of electrical compatibility between rolling stock and infrastructure
NR/SP/SIG/50002	Methodology for the demonstration of compliance with single rail reed track circuits on the AC railway
NR/SP/SIG/50003	Methodology for the demonstration of electrical compatibility with double rail reed track circuits on the DC railway
NR/SP/SIG/50004	Methodology for the demonstration of compatibility with DC (AC-immune) track circuits
RT/E/C/50005	Methodology for the demonstration of compatibility with 50 Hz single rail track circuits
NR/SP/SIG/50006	Methodology for the demonstration of compatibility with 50 Hz double rail track circuits
RT/E/C/50007	Methodology for the demonstration of compatibility with HVI track circuits
RT/E/C/50008	Methodology for the demonstration of compatibility with TI 21 track circuits
RT/E/C/50009	Methodology for the demonstration of compatibility with FS2600 track circuits on the DC railway
NR/L2/SIG/50010	Methodology for the demonstration of electrical compatibility with train detection system in use on non-electrified lines
NR/SP/SIG/50011	Methodology for the demonstration of compatibility with axle counters
NR/SP/SIG/50012	Methodology for the demonstration of compatibility with TPWS track sub-system
RT/E/G/50014	Methodology for the demonstration of Compatibility with Lineside Equipment
NR/SP/SIG/50015	Methodology for the demonstration of compatibility with Reed FDM systems on the AC and DC railways
NR/SP/TEL/50016	Methodology for the demonstration of Compatibility with Telecommunications Systems
RT/E/C/50018	Methodology for the demonstration of compatibility with interlockings

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NR/SP/SIG/11752	Train detection
ITU-T Directive Volume IV	Inducing currents and voltages in electrified railway systems
ITU-T Dir Vol V	Inducing currents and voltages in power transmission and distribution systems
ITU-T Dir Vol VI	Danger and disturbance
ITU-T Dir Vol VII	Protective measures and safety precautions
ITU-T Dir Vol VIII	Protective devices
ITU-T Dir Vol IX	Testing methods and measuring apparatus
ITU-T Rec. G.117	Transmission aspects of unbalance about earth (Definitions and methods)
ITU-T Rec. K.17	Tests on power-fed repeaters using solid state devices in order to check the arrangements for protection from external interference
ITU-T Rec. O.41	Psophometer for use on telephone-type circuits
ITU-T Rec. O.9	Measuring arrangements to assess the degree of unbalance about earth
IEC 60479-2	Guide to effects of current on human beings and livestock — Part 2: Special aspects relating to human beings
EN 50121-2	Railway applications — Electromagnetic compatibility. Part 2: Emissions of the whole railway system to the outside world
EN 50121-4	Railway applications - Electromagnetic compatibility. Part 4: Emission and immunity of the signalling and telecommunications apparatus
EN 50122-1	Railway applications: Fixed installations Part 1: Protective provisions relating to electrical safety and earthing
EN 50238	Railway applications: Compatibility between rolling stock and train detection systems
EN 50388	Railway applications. Power supply and rolling stock. Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability
G5/4-1	Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission systems and distribution networks in the United Kingdom

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1 Purpose

This guidance note provides an overview of the coupling between traction current and induced voltages on lineside cables and the effects this has on personal safety, and equipment malfunction.

It describes the influencing factors, potential risks and available mitigations to reduce the effects.

It is also a useful reference to mandatory standards which control the risks associated with traction-induced voltages on lineside cables.

2 Scope

Magnetic induction affects all conductors that run in parallel with electric traction systems.

This guidance note covers traction coupling to lineside cables in general, but only covers the immunisation of telecommunications systems. Signalling has a suite of standards (NR/L2/SIG/50xxx) which cover the immunisation of specific systems, so the effects of electric traction on signalling are not covered.

This document updates much of the technical information provided in BR 13422, although it does not reproduce in detail the methodology for calculating induced longitudinal voltage, as this is now achieved with modelling.

3 Definitions

AC

Alternating Current

Accessible voltage

The voltage between two accessible conductors under operating conditions which can be bridged by persons, the conductive path being conventionally from hand to both feet through the body or from hand to hand (horizontal distance of 1 m to a touchable part)

ALARP

As Low As Reasonably Practicable

ALEH

Active Lineside Equipment Housing

Autotransformer (AT)

A transformer with a single winding that is centre tapped. The centre tap is connected to the traction return earth circuit. The +25 kV terminal is connected to the catenary and the -25 kV terminal is connected to the autotransformer feeder.

Autotransformer electrification system

A system of electrification in which the supply transformer secondary voltage is 50 kV, centre tapped to earth. Two live 25 kV secondary connections are made to the catenary and autotransformer feeder wires respectively. The earthed centre tapping is connected to the traction return circuit.

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Autotransformer feeder (ATF)

A bare live conductor provided in an autotransformer electrification system connecting the –25 kV terminals of adjacent autotransformers. The autotransformer feeder is normally mounted upon 25 kV insulators directly above the mast on cantilever and headspan structures, or directly above the uprights of a portal structure.

Autotransformer site (ATS)

The site of lineside equipment including autotransformers arranged together for the purpose of providing immunisation to signalling and telecommunications equipment and remote switching of the power supply to the overhead line equipment. Some autotransformer sites may also be track sectioning sites.

Bond

A suitably designed conductor electrically connecting together conductive parts

Booster transformer (BT)

A device to induce into the return conductors, virtually the whole of the traction return current, in order to reduce to a minimum electrical interference with communication circuits.

Catenary

The suspension cable from which the contact wire is suspended via droppers

Combined screening conductor (CSC)

Screening conductor bonded to earth farms (like an MSC) and also to traction return (like an RSC).

Common-mode voltage (V_{CM})

Voltage with respect to earth on all conductors in a cable. This may be different to longitudinal voltage.

Contact line

A conductor system for supplying electric energy to vehicles through current collecting equipment.

Continuity bond (traction)

A bond across an electrical discontinuity in the traction return rails, e.g. at points and crossings, trap points and expansion points.

Copper section

The copper cable telecommunications network between two adjacent access nodes or between a core node and an adjacent access node (FTN term)

Copper half-section

One half of a copper section which has been divided and its two halves kept electrically isolated to maintain induced voltages within permissible limits (FTN term)

Cross bond (traction)

A bond between the traction return rails of the same track or adjacent tracks.

CTRL

Channel Tunnel Rail Link

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DC

Direct Current

Distribution cabinet

A lineside telecommunications cabinet, with no power supply or climate conditioning equipment, that manages the connection of tail cables to the copper cable network

DNO

Distribution Network Operator

Double rail return (DRR)

Track in which both rails are used to carry the return current from the train to the source

E&P

Electrification and Plant

E&P route

(Large) cable route that carries electrification cables in DC electrified areas

Electrification parameters

The configuration of the traction electrification system for a particular area. For example, 25 kV with booster transformers and return conductor on a DRR, 2-track railway

EMC

Electromagnetic compatibility

EMU

Electromotive unit

Fault current

The current which flows as a result of an unintentional electrical fault on the electrification system, e.g. a short circuit or flashover.

Feeder station

A building or compound containing electrical switchgear and equipment to which the main supplies from the Electricity Supply Industry are brought and from which the overhead line equipment is supplied.

FTN

Network Rail's Fixed Telecom Network

Half-section

Refer to copper half-section above

Immunisation

The action of reducing effects of induced voltage on lineside systems

Impedance bond

A device which, whilst allowing the traction return current to flow freely, so impedes the flow of track circuit current as virtually to isolate two track circuits one from another.

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Lineside services

Services such as SPTs, level crossing phones and SSI signal cables that are required for the running and control of the operational railway

Longitudinal conversion loss (LCL)

Longitudinal conversion loss is the logarithmic ratio between longitudinal voltage and transverse voltage.

Longitudinal voltage (V_L)

Voltage developed along the length of a cable due to magnetic induction. This may be different to common-mode voltage.

Mid-point connection (MPC)

A bond between the return rail and the return conductor located half-way between booster transformers

Mid-point track sectioning cabin (MP TSC)

A track sectioning cabin at a neutral section in the contact wire

Mutual screening conductor

A large conductor which runs in the telecommunications trough whose sole purpose is to reduce the coupling between the traction system and telecommunications and signalling cables. The conductor is earthed to earth farms at regular intervals. See also return screening conductor.

Overhead line equipment

An arrangement of wires, suspended over the railway line, for supplying electricity to electric trains, together with associated fittings, insulators and other attachments including feeders, autotransformer feeders, overhead line switches, jumpers and return conductors.

Parallelism

The presence of high current/high voltage lines (e.g. traction power conductors and National Grid HV lines) running parallel with the railway

Pantograph

A contact mechanism mounted on the roof of electric traction units, which, when raised, presses against the underside of the contact wire and collects current from the overhead line equipment

Psophometric

Matching the audio response of the human ear. A psophometric filter is a filter that matches the audio response of the ear. A psophometric voltage is a wide band signal which has been modified by a psophometric filter.

Railhead

The uppermost surface of a running rail

Rail joint bond

A bond across a joint in the running rails.

REB

Relocatable equipment building

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Red bond

A bond, often carrying traction current, which if disconnected, could result in either the bond or the equipment to which it is connected rising to a voltage in excess of the permitted accessible or touch voltage.

Return conductor to rail bond

A bond from the traction return rail to the return conductor, often called a “mid point connection”. These will usually be red bonds.

Return conductor (RC)

A conductor provided in an electrification system to carry traction return current back to a feeder station for the purpose of suppressing electromagnetic interference in telecommunication and signalling circuits.

Return rail (RR)

A running rail that is used to complete the traction return circuit.

Return screening conductor (RSC)

A large conductor in the telecommunications trough designed to reduce the longitudinal voltage developed on lineside cables which is connected at regular intervals to a traction return rail. See also mutual screening conductor.

S&T

Signalling and Telecommunications

Signal post telephone (SPT)

A lineside phone mounted on or near a signal, provided to enable drivers stopped at a signal to speak to the signaller

Single rail return (SRR)

Track where one rail per track only carries the return current back to source

Stub cable

A signalling or telecommunications copper cable with one end that does not terminate in an access node or a core node

Tail cable

Signalling or telecommunications cables, typically containing 2 pairs, that connect lineside services such as SPTs to network distribution points

Terminal equipment

Telecommunications equipment connected to the end of a telecommunications cable, such as a telephone or modem

Touch voltage

The voltage under fault conditions between parts when touched simultaneously

Track sectioning cabin (TSC)

A building containing enclosed electrical switchgear and equipment which is arranged to connect together a number of sections of overhead line equipment.

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Transverse voltage (V_T)

Voltage between the two wires forming a telecommunications pair as a result of V_L and cable imbalances. This voltage appears across the terminal equipment (e.g. earpiece) as noise. Sometimes referred to as differential mode voltage.

Voltage limiting device

A device which protects circuits from excessively high voltages typically caused by lightning or power faults. Sometimes referred to as surge arrestors. Examples include gas gap devices, transient suppressors, protection diodes, etc.

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4 Introduction



Figure 1 - Electric train and AC overhead line equipment

Electric traction systems, and AC traction (Figure 1) in particular, induce voltages onto any lineside conductors that run in parallel with the railway. This presents risks to personal safety and to the performance of lineside systems, both of which need to be managed.

Figure 2 provides an overview of the transfer of electromagnetic energy from traction current (or faults in the OHLE), via the magnetic field it generates to the induced longitudinal voltage on lineside telecommunications cables and the transverse voltage that results between the conductors in a telecommunications pair.

The major factors that influence the magnitude of the EM energy at each stage are listed in the boxes below.

The diagram also relates the longitudinal and transverse voltages to their potential safety and performance effects on telecommunications systems.

This guidance note explains the cause of induced voltages on lineside cables, the possible effects on telecommunications systems and outlines the techniques used to minimise the induced voltage and verify that the telecommunications systems will continue to operate satisfactorily without risk to personnel.

It also provides references to standards that define the mandatory requirements to control the risks associated with induction. Although all lineside conductors are affected by magnetic induction, only telecommunications systems are covered in this

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guidance note. Risks to signalling systems are covered in product-specific standards in the series NR/L2/SIG/50xxx.

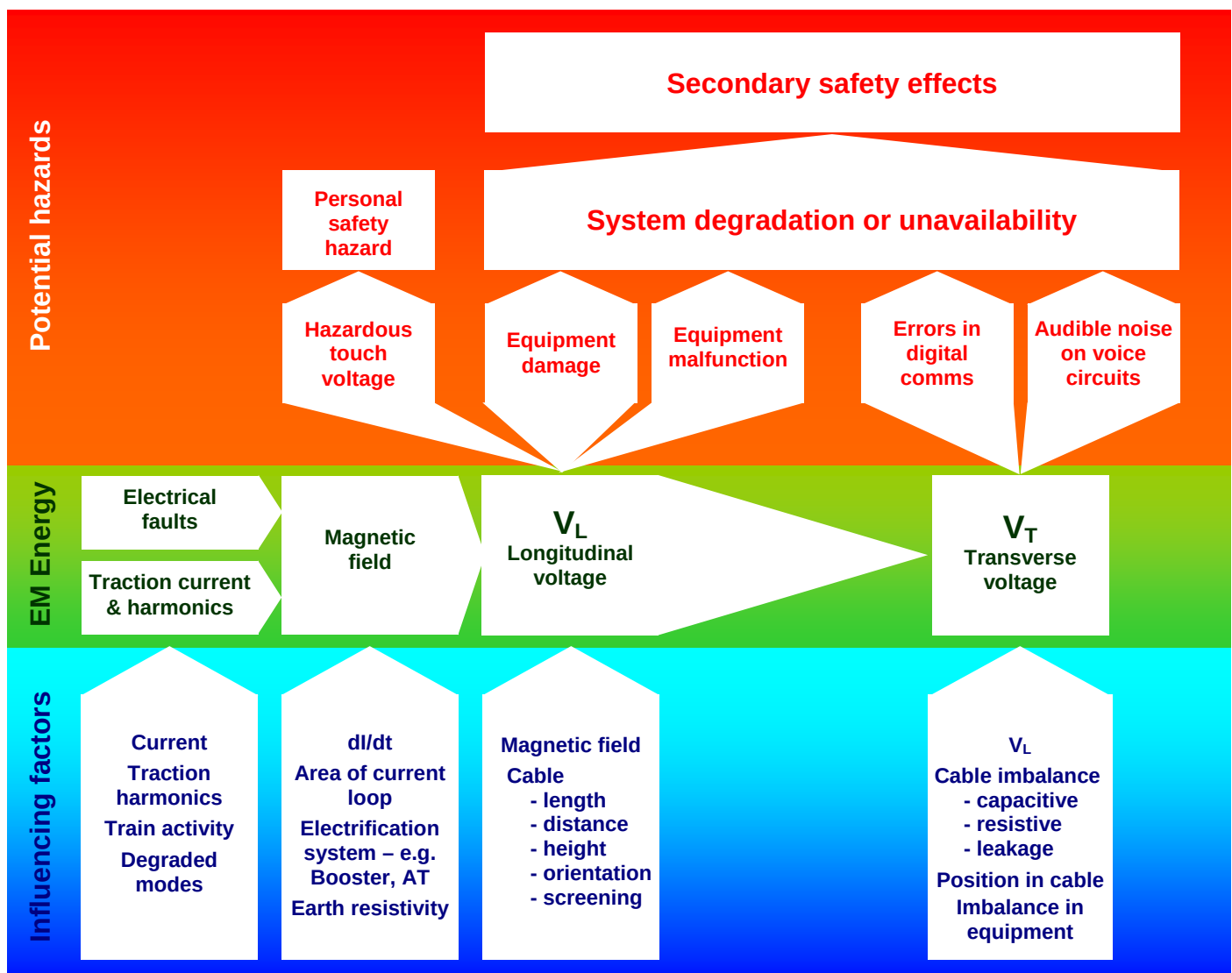


Figure 2 - Effects of electric traction on telecommunications systems

4.1 Risks to telecommunications systems due to electric traction

Electric trains are supplied by either direct current (DC) or alternating current (AC). Both electrification systems have the theoretical potential of causing:

- electric shock due to unsafe touch and accessible voltages
- interference to lineside systems
- damage to lineside systems

In practice, the effect of DC traction on telecommunications systems is relatively low. Consequently AC traction and its effects are covered in greater detail in this guidance note.

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4.2 Electric Traction Systems

There are a number of different electric traction systems in use in the UK:

- AC systems
 - 25 kV “Classic” overhead supply
 - Rail return
 - Rail return with return conductor
 - Booster transformer
 - Booster transformer with return conductor
 - ± 25 kV Autotransformer
- DC systems
 - 750 Vdc third rail (Network Rail and other railways)
 - 650 Vdc fourth rail (London Underground)
 - 1500 Vdc overhead (tram systems)

Section 5 describes the various types of 25 kV “Classic” system, their effects on lineside conductors, and how those effects may be mitigated.

Section 7.1.4 outlines the autotransformer system, which was first deployed on the West Coast Main Line around 2006.

DC traction is covered in Section 8.

5 AC Traction - 25 kV Classic System

AC traction electrification current is derived from National Grid supplies and is supplied to trains through a conductor called a “contact wire,” which runs above the running rails. Trains draw current through a retractable arm (a pantograph), which makes contact with the contact wire, and after travelling through the motor the current returns to source through one or both of the running rails as depicted in Figure 3.

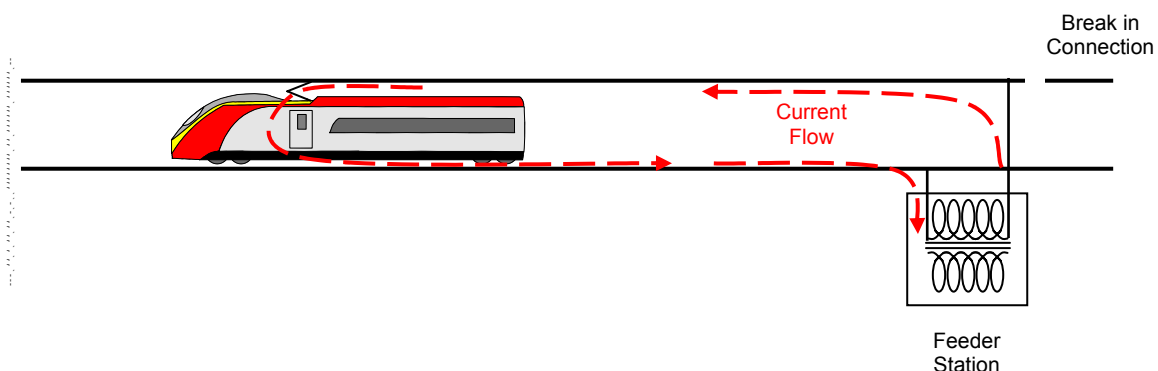


Figure 3 - Simplified feeding AC electrification

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5.1 The power supply and distribution system¹

Power from the electricity grid is supplied at 400 kV ac, 275 kV ac, 132 kV ac, or 66 kV ac at 50 Hz, at each feeder station. The feeder station has two independent single-phase transformers that convert the input supply to 25 kV ac. Circuit breakers and isolators are used to connect the 25 kV to the appropriate sections of the track, as shown in Figure 4.

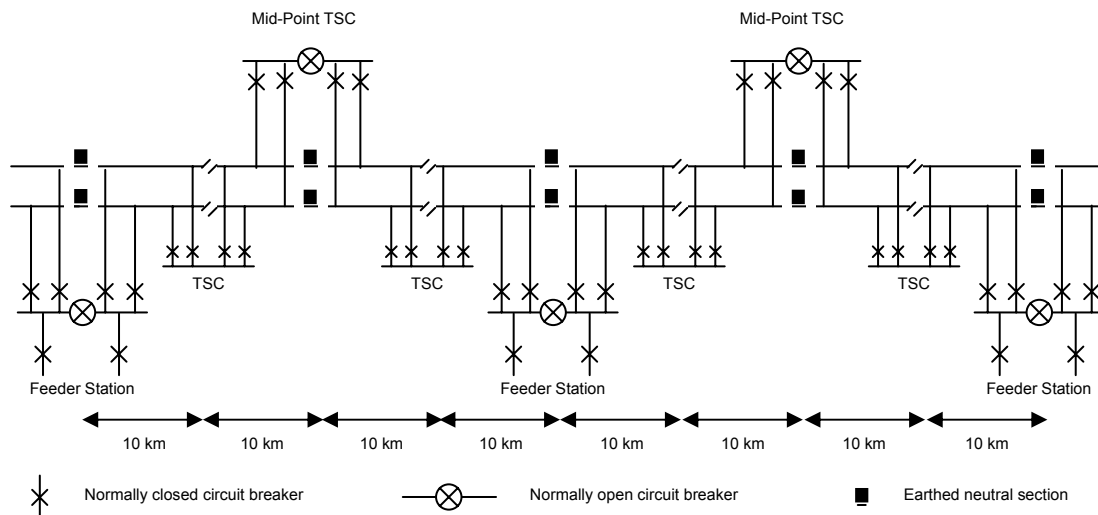


Figure 4 - AC traction power supply and distribution system

Feeder stations are normally placed between 30 and 40 km apart, although the gap is far greater in some instances. Adjacent feeder stations are fed from different phases of the National Grid supply and are electrically separated by busbar couplers at mid-point track sectioning cabins (TSCs). Where the power on the contact wire changes from one phase to another, a gap is made in the contact wires and a short section of contact wire, called a “neutral section,” is interposed between them which is connected to the traction return rail (i.e. earthed). Magnets are located on the sleeper ends before and after a neutral section, which operate a receiver on the electric vehicle to disconnect and then re-apply power. This prevents arcing at the pantograph as the train passes from one electrical section to another.

The train current varies according to whether it is accelerating, coasting or regenerating and is highly dependent on the type of train. Trains may draw up to a nominal 300 A. The current entering an electrical section varies significantly depending on the class of locomotive and the number of trains in section. Where there are several tracks and high congestion, the maximum may be 1000 A or more.

The system is typically designed to prevent fault currents exceeding 6000 A. “Bird strikes” are one of the major causes of electrical faults, when a bird bridges the air gap between the 25 kV catenary and an earthed structure, such as a bridge. It has been estimated that the rate of bird strikes in the UK is 1 per km per year. This is equivalent to 10 strikes per year for a 10 km cable.

¹ This section outlines a typical AC electrification system, but local conditions may vary from this description.

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Bonding across traction return rail joints and between the traction return rails of all tracks is provided to ensure an adequate return path for traction return current, and avoid excessive rail to earth voltages.

5.1.1 OHLE Dimensions

The typical dimensions of the overhead line conductors for a 2-track railway are shown in Figure 5. All dimensions are referenced to the top of the outermost rail. Also shown is a -25 kV autfeeder, which is only used with an autotransformer system. In a rail return system, the return conductors would not be present. In some cases the locations of the conductors may differ from this figure, particularly where it is necessary to avoid structures such as bridges and tunnels. Distances between tracks may vary significantly.

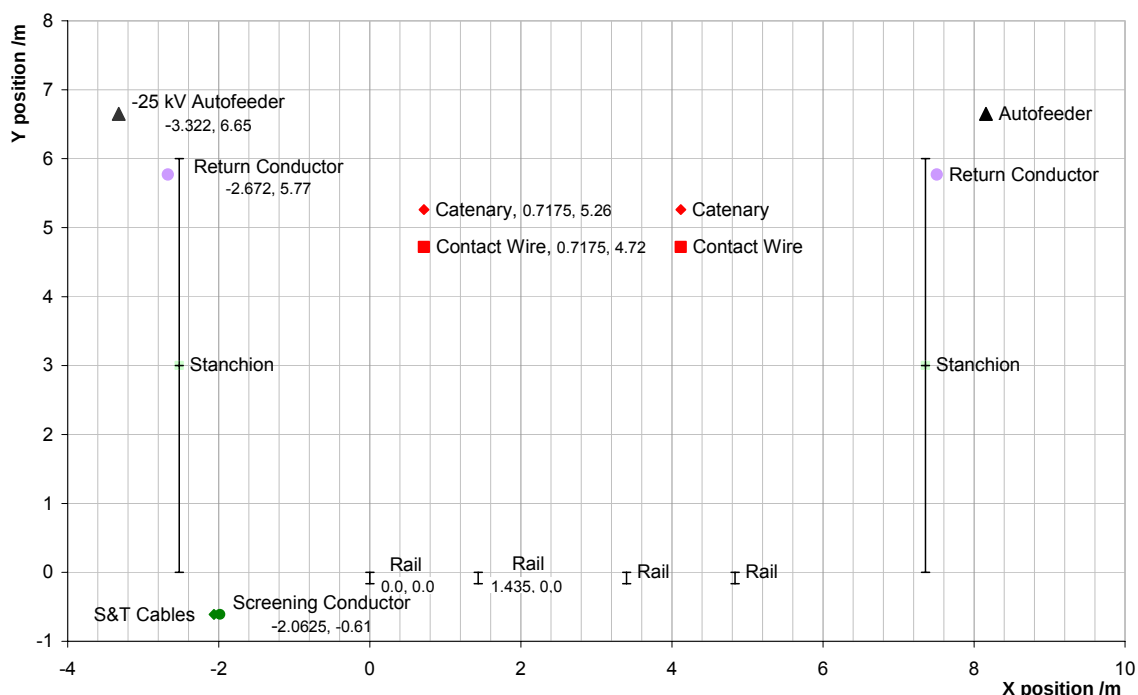


Figure 5 - Typical overhead line dimensions for a 2-track railway

5.1.2 Normal feeding

Under normal feeding arrangements, one of the transformers at the feeder station powers the line in the up direction to the next mid-point track section cabin (TSC). The other transformer similarly feeds the line in the down direction, as shown in Figure 6.

Mid-point TSCs are used to enable each track to be fed from one of two directions, which prevents a failure in a single circuit breaker from stopping traffic. At a mid-point TSC, a neutral section is introduced into the contact wire which separates the electrical sections and prevents the train from drawing an arc that could inadvertently connect the sections.

Traction current is fed directly from the feeder station via the contact wire, but also via the other catenaries and the links at the next track sectioning cabin.

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5.1.3 First emergency feeding

Under first emergency feeding, when one of the transformers at the feeder station has failed or is unavailable, the remaining transformer is used to power the lines in both the up and down directions to the mid-point TSC, as shown in Figure 7. This is achieved by isolating the failed transformer and closing the “bus section” circuit breaker at the feeder station. Under these circumstances full service performance is maintained.

5.1.4 Second emergency feeding

Under second emergency feeding, when both supplies to a feeder station are unavailable, the adjacent feeder station will provide power to the lines up to the faulty feeder station, as shown in Figure 8.

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