COMPANY MAIN TOPIC [PRODUCT]

Rail Power Systems

NEW CONCEPT FOR SYSTEM SEPARATION SECTIONS INSTANCING THE NEW INSTALLATION AT ZEVENAAR, (NL)

English

Authors: Jens Northe (DE),
Dr. Andriy Zynovchenko, Offenbach am Main (DE),
Richard Rieksen, Arnhem (NL),
Jeroen Vonk, Utrecht (NL)

New concept for system separation section instancing the new installation at Zevenaar (NL)

Jens Northe, Andriy Zynovchenko, Offenbach am Main; Richard Rieksen, Arnhem (NL), Jeroen Vonk, Utrecht (NL)

System separation sections are core elements to securely separate different traction power supply systems. Design, function and arrangement are dependent on operational and local constraints. A new concept for system separation sections in the Netherlands has been introduced. A pilot installation has been implemented at Zevenaar which is described from concept up to system verification.

NEUES SYSTEMTRENNSTELLENKONZEPT AM BEISPIEL DER ANLAGE IN ZEVENAAR (NL)
Systemtrennstellen sind wesentliche Elemente zur Trennung unterschiedlicher Bahnenergieversorgungssysteme. Aufbau, Funktion und Anordnung sind abhängig von betrieblichen und örtlichen Gegebenheiten. Für die Systemtrennstellen in den Niederlanden wurde ein neues Konzept entwickelt und in Zevenaar als Pilotanlage umgesetzt.

NOUVEAU CONCEPT POUR DES SECTIONS DE SEPARATION DE SYSTEME A L'EXEMPLE DE L'INSTALLATION A ZEVENAAR (NL)
Les sections de séparation de système représentent des éléments essentiels pour la séparation de différents systèmes d'alimentation en énergie ferroviaire. La conception, la fonction et la disposition dépendent des contraintes de l'exploitation ainsi que des conditions locales. Pour les sections de séparation aux Pays-Bas a été développé un nouveau concept et réalisé à Zevenaar sous forme d'une installation pilote.

1 Task

System separation sections are technical means of separating different railway power supply systems. Their main task is to prevent damage that may occur

- to the infrastructure as a result of the direct electrical connection of two different power supply systems or
- to traction vehicles by operating a main circuit that is not adapted to the specific power supply system.

The structure of the contact line system in a system separation section can be understood by the splitting into electrical zones. Similarly, there are requirements in the technical specifications for interoperability and standards that govern the interaction of the contact line structure and pantograph assembly. In contrast, the design requirements of the track return circuit are only specified by the operator – if at all – even though an electrical connection takes place via the wheelsets and vehicle bodies during the transition between a d.c. and a.c. power supply. This must be evaluated in respect of compatibility, especially of the return current path. All aspects for Netherlands' system separation sections are covered by the ProRail specification OVS00054 [1].

In addition to the structure of the feeding and return circuit, a monitoring system is always to be provided, which detects any improper passage through a system separation section and switches off the power supply before impermissible operating conditions can occur.

2 Legal and normative specifications

The basic and binding specifications for system separation sections in the Trans-European Networks (conventional and high-speed) and their passage are defined in the Technical Specifications for Interoperability (TSI) for Energy [2] in Section 4.2.16 and in the TSI Locomotives and Passenger Rolling Stock [3] in Section 4.2.8.2.9.8. Here, the TSI Energy differentiates between system separation sections that can be passed with a raised pantograph versus those that must be passed with a lowered pantograph. For both types, the passage must be off-load and, starting at a speed of 160 km/h, the vehicle must also use automatic sequence control.

Specific requirements for setting up the contact line structure and the pantograph arrangement are stated in the current standards EN 50367 [4] and EN 50388 [5].

Thus, EN 50367 specifies:

- the basic requirements for neutral sections in Section 5.2.7
- the minimum distances to be maintained between pantographs at certain speeds in Table 8 and
- requirements for the length of a neutral section and the minimum pantograph spacing for passing the neutral section in Appendix A.1 (Figure 1).

Whereas EN 50367 only refers to general neutral sections, EN 50388 differentiates between phase and system separation sections in Section 5.2. Nonetheless, the stated requirements are only slightly more specific than in the TSI Energy.

3 Requirements for design and arrangement

In principle, system separation sections can be arranged in railway stations with system change or on open tracks.

The advantage of railway stations with system change is that trains can enter and leave the station without a system change and thus without any impact on the tractive force. The changeover takes place when the vehicle is at a standstill during a scheduled stop, by switching both the power supply system to the catenary as well as the traction equipment of the vehicle. For this reason, all tracks that are used during the system change must be provided with technical equipment that:

- permits the specific changeover of the power supply system and
- has been designed for the highest system voltage and highest fault current
  - the contact line including section insulators and disconnectors, as well as
  - the return circuit including the earthing system.

A neutral zone must be provided for each available entry/exit, as it can never be completely ensured that the contact lines of the railway station and those following in the direction of travel are supplied from the same system. A high number of switching operations of the fixed installation and a comparatively complex contact line system with numerous neutral sections are to be evaluated against the advantage

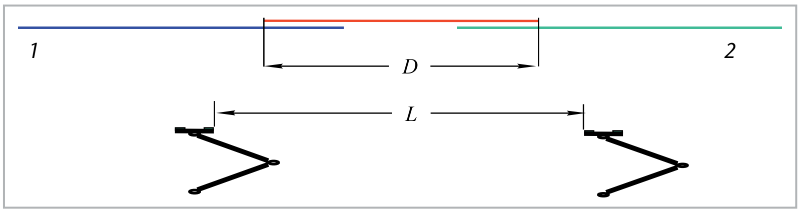


Figure 1:
Principle of a neutral section: the condition $L > D$ applies (Graphic: Figure A.1 from EN 50367).
1 Phase/System *1*
2 Phase/System *2*
D Overall length of the neutral section as the distance between adjacent systems/phases
L Inner distance between two adjacent pantographs

of system changes made at a standstill. Reference [6] shows an example of an implementation and the respective technical requirements to be taken into consideration.

System separation sections on open track avoid power supply changeovers. However, they do require switchgears

- for protection tripping in the event of improper passage and
- for long neutral sections to enable vehicles that have come to a stop to move out again.

When determining the structure and length as well as the location of a system separation section, the following constraints are to be considered:

- There must be a minimum distance to scheduled stopping points to enable passing through the system separation section at sufficient speed.
- The location must be in as flat a section of the route as possible to avoid unintentional stops during an ascent.
- The location must be at a sufficient distance from special structures such as bridges and tunnels to avoid disrupting passers-by as well as forced stops at unfavourable locations.
- The location must be at a sufficient distance from the supply points in terms of short-circuit currents and their frequency of occurrence. Corrective actions need to be determined in case of insufficient distances.

At the *acrps* 2015 conference, one of the presentations [7] included a description of simple implementation of a system separation section on open track and a large distance between constraint points.

Irrespective of the system change model, the operational changeover of the main circuit on board of traction vehicles for alignment with the respective supply system is always required. The procedure is to be specified by the infrastructure manager.

When determining the design and selecting the location of a system separation section – for example, in an expanded crossroads area – the criteria may also include the number of different types of traction vehicle as well as the different train operating companies (TOCs) using a particular track section. This is particularly important if the process is not triggered via automatic train control.

4 System separation sections in the Netherlands

Up to now, system separation sections between DC 1 500 V and 1 AC 25 kV 50 Hz in the Netherlands have been constructed in the form of a short neutral section. In areas of nearby constraint points the shortest length is down to 65 m. They are to be passed with the pantograph lowered. This results in the following layout for the contact line:

- The continuous main contact line is electrically interrupted by two zones insulators and a neutral zone of around 45 m in length.
- A second contact wire, referred to as a detection wire, is guided in parallel to the main contact line. The detection wire comprises five sub-sections. At the beginning and end of the wire is a neutral zone for lowering the detection wire to the level of the main contact line; next to each of the neutral zones is a 10 m zone that is connected to the return circuit of the a.c. or d.c. system. Parallel to the neutral zone in the main contact line is a neutral zone in the detection wire.
- The zones are respectively separated by traversable section insulators, which have an insulating length of 1.3 m.

Unintentionally passing through the system separation section with a raised pantograph will lead to a direct connection of the contact line and the return circuit. This is identified by a short-circuit detection and results in both power supply systems of the affected track being tripped in order to prevent the still elevated pantograph from causing a second short circuit at the end of the passage. The local short-circuit detection can differentiate between improper passage and a catenary fault, thus enabling quick re-energizing; however, it cannot prevent the impacts of short circuits on the networks.

5 The railway power supply situation in Zevenaar

In Zevenaar, a Dutch town near the German border, the railway line from Oberhausen branches into two routes: one route for passenger traffic, heading to Arnhem, and the other – the *Betuweroute* heading towards Rotterdam – for freight. Since the construction of the *Betuweroute* at the turn of the millennium, it has been supplied with 2 AC 50 kV/25 kV 50 Hz. The track section from Zevenaar to the border at Emmerich continued to be supplied with the conventional DC 1 500 V system of the Netherlands.

Passenger traffic was previously limited to the Frankfurt – Amsterdam international ICE route. In contrast, numerous freight trains with different types of locomotives and of several TOCs travelled the *Betuweroute* being part of the Genoa – Rotterdam thoroughfare. Because of the network layout, freight trains passed through two system separation sections, from 1 AC 15 kV 16.7 Hz to DC 1 500 V near the border, and from DC 1 500 V to 1 AC 25 kV 50 Hz at the beginning of the *Betuweroute*.

6 System separation in Zevenaar

6.1 Status prior to conversion

The previous system separation section in Zevenaar was located around 2 km from the next a.c. substation, OS Zevenaar. In the event of improper passage from the area supplied with 25 kV, this led directly to high short-circuit currents of over 12 kA with the respective stress on the electrical equipment as well as observable electric arcs and crackling in the periphery. At the same time, this also resulted in impermissibly high voltage dips in the feeding 3AC 150-kV network of *TenneT*, the utility company.

As a freight route, the *Betuweroute* is used by several TOCs with different types of traction vehicles. The system separation section was indicated by signals, the main switch had to be opened by the traction vehicle driver and the pantograph had to be lowered; there was no automated passage. As a result, short-circuit tripping was a frequent occurrence. Unlike catenary faults, voltage sags that result from inattention are certainly not inevitable operating incidents. This resulted in the decision to stop using OS Zevenaar substation in conjunction with the previous structure of a system separation for the power supply to the *Betuweroute*.

6.2 Strengthening project

In mid-2016, to increase efficiency of the *Betuweroute*, the operator of the Dutch rail network *ProRail* converted the power supply for the track section between Zevenaar (NL) and Emmerich (DE) from DC 1 500 V to 1 AC 25 kV 50 Hz. This changeover also necessitated a relocation of the previous system separation section from the freight route to the passenger route (Figure 2).

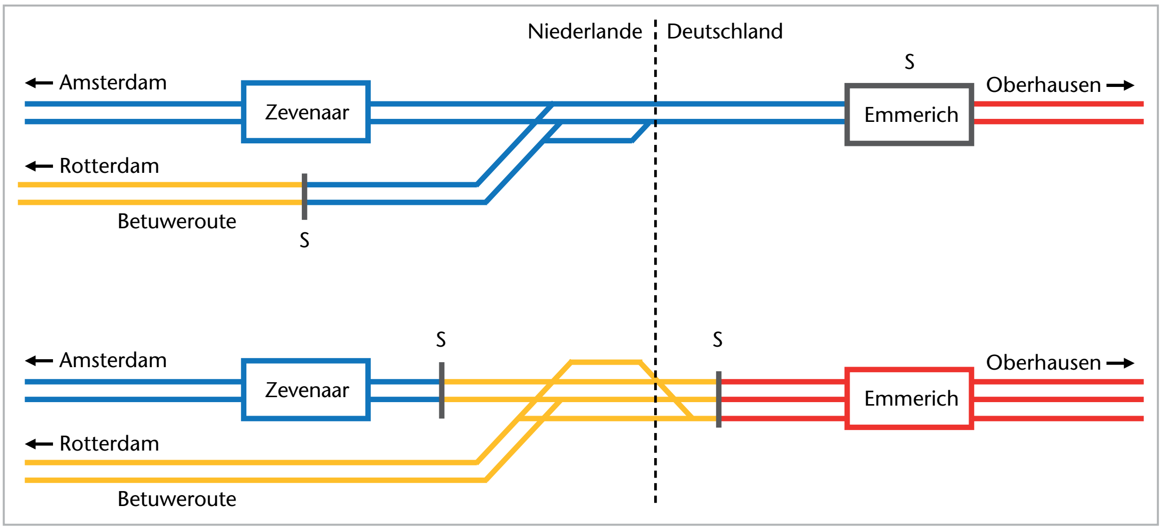


Figure 2:
Basic route map between Zevenaar/NL and Emmerich/DE (Figures 2 to 4, 6 and 7: RPS).
above Current state
below Target state; location of the system separation section already implemented, 3-track expansion planned for the German side
S System separation section

Railway power supply
blue DC 1 500 V
red 1 AC 15 kV 16.7 Hz
yellow 1 AC 25 kV 50 Hz

In addition to the previous traffic on the freight route and long-distance passenger transport, local public transport between the Netherlands and Germany has started in December 2016. The regional line RB35 connects Arnhem (NL) with Düsseldorf (DE) with stops next to the border at Zevenaar and Emmerich.

The following significant constraints from the rail operations needed consideration when selecting the location for the new system separation section:

- sufficient distance from the Zevenaar railway station
  - in order not to affect domestic rail traffic, and
  - to allow for the appropriate speed for outbound trains on international routes
- sufficient distance from the junctions area with the *Betuweroute* in order to impede *Betuweroute* traffic as little as possible in the case of tripping the system separation section.

The site that was chosen is located approximately 800 m from the railway station. This site enables acceleration to a sufficiently high speed so that trains can safely roll through the system separation section with the pantograph lowered. However, the site is located very close to the first track junction – around 200 m away – so that the length of supply section 1912 is not sufficient to ensure safe operation with all traction vehicle configurations and travel directions. In particular a travel on the south track from east to west with an *ICE2* could lead to transfer of voltage on the catenary from supply section 1053 to already switched-off supply section 1912. To ensure safe operation, it was therefore decided that in the event of improper passage on the south track, both supply section 1912 and section 1053 – which also spans the junction area and is thus vital to *Betuweroute* operations – would be switched off. The influence on *Betuweroute* operations is classified as negligible, as setting up a route takes around the same amount of time as re-energizing after improper passage through the system separation section.

6.3 Implementation

The short-circuit detection method previously specified by the customer for system separation sections gave rise to the following situations: in the event of improper passage, the vicinity is disturbed by crackling and electric arcs, and when nearby a substation there is an impermissible voltage sag in the feeding 150 kV three-phase grid.

Together with local planning of the system separation section and on the basis of operational experience and constraints, the functional principle was redefined as well. In consequence, the previous installation, comprising the zones with earthed return circuit and the neutral zone at the beginning and end of the system separation section, was extended at each end with a 10 m voltage detection zone. In order to avoid changing the overall length of the system separation section, the length of the centre neutral zone was reduced to under 20 m.

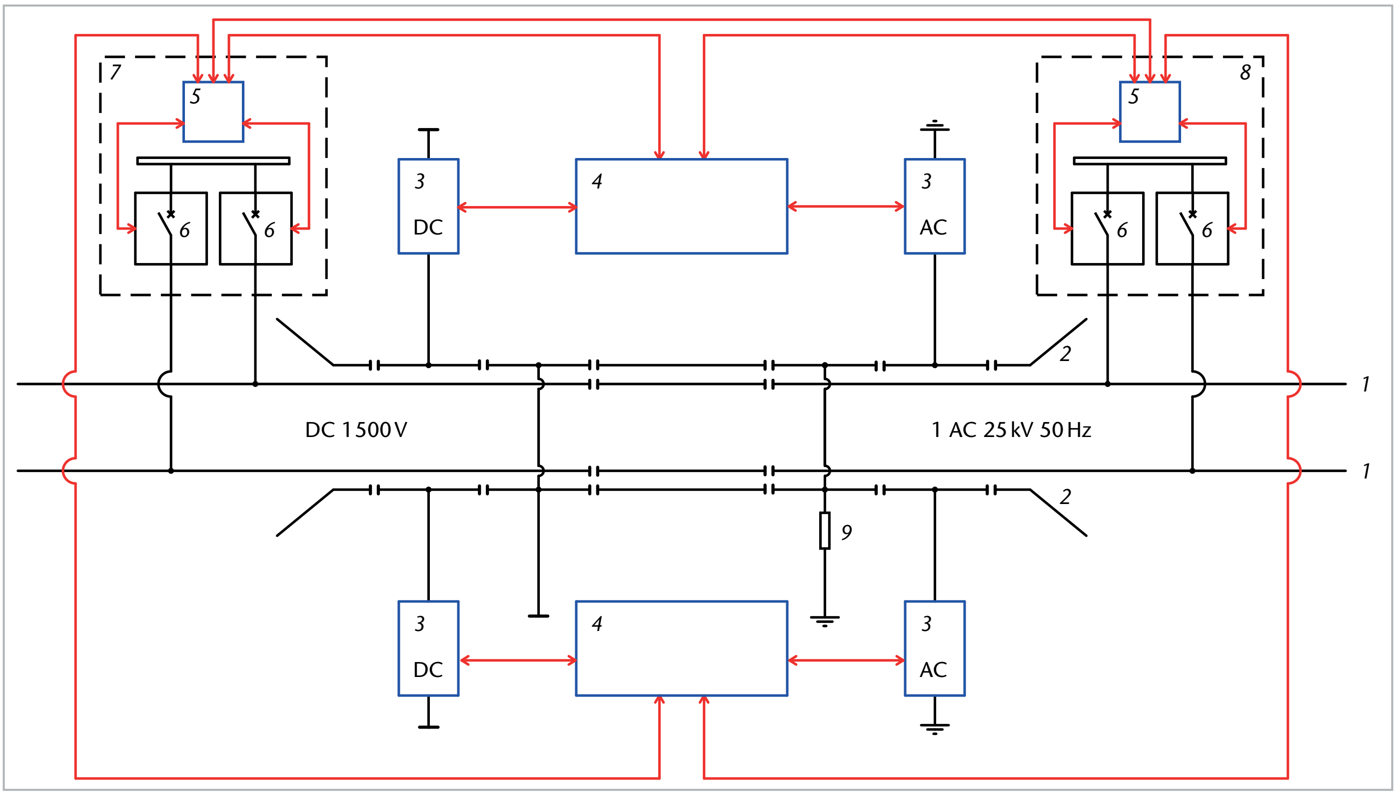


Figure 3:
Design of monitoring system.

black Primary circuits
blue Measurement and control cabinets
red Communication links

1 Main contact line with the a.c./neutral/d.c. zones
2 Detection wire subdivided into seven zones
3 Voltage measurement
4 Track-side detection cabinet
5 Interface cubicles inside the substation
6 Circuit breaker or d.c. high-speed circuit breaker
7 DC 1 500 V substation
8 1 AC 25 kV 50 Hz substation
9 Short-circuit current limiting

With the voltage detection zones now upstream, improper passages are now detected and the circuit breakers in the substations are opened before the pantograph enters the short-circuit zone. However, these zones, which are connected to the respective return circuit, are retained at the back-up level in order to prevent bypassing the power supply systems even when the voltage detection is switched off. Short circuits are detected by the respective circuit breaker protection.

7 Operating principle and structure

From 2003 to 2006, Rail Power Systems GmbH (RPS) – operating under the company name Balfour Beatty Rail GmbH Power Systems and in collaboration with Nuon (now Liandon) – constructed the substations, autotransformer stations and system separation sections along the *Betuweroute*. In summer 2015, RPS was awarded the contract to design and construct the monitoring system for the system separation section.

Essential sub-steps included:

- conceptual design of detection and transmission, in consideration of
  - the length of the detection zone
  - the speed of travel
  - a delayed detection, for example if a pantograph bounces
  - switch-off times of the dedicated circuit breakers
- the design of the voltage detection, particularly with regard to possible capacitive and resistive interference
- selection of apparatuses and design of the control cabinets
- system check of the detection equipment including detection sensitivity, minimum triggering threshold and activation time
- on-site system function test
- system integration support including train runs

The structure of the detection system as carried out is shown in Figure 3. The 10 m length for the voltage detection zone, in conjunction with the maximum 130 km/h travel speed, taking all tolerances into account, results in a worst-case time of 250 ms for together detection and tripping. If this is further reduced to include the switch-off times in the substations and possible delay of voltage transmission from the pantograph to the detection wire, the system has only 100 ms available, based on

- voltage detection at the system separation section,
- evaluation of the voltage curve as well as
- transmission and making the trip signal available in the substation

100 ms is not a short period, but in view of the 10 ms response time for a typical auxiliary relay, it is not really that much, either. The apparatuses and locally distributed circuit configuration were therefore selected and developed with particular attention paid to the processing time.

Voltage transformers were used on the a.c. side and voltage transducers on the d.c. side for voltage detection. The contact line zones connected to the respective voltage detectors are limited by multiple insulators; in many cases, they run parallel to zones operating under voltage. System analyses were carried out for verification of safe long-term operation. They demonstrated that additional protective circuitry on the voltage detectors is necessary. In view of short primary connections and in respect of human safety, voltage detectors were mounted on the suspension masts at a height of above 4 m and thus far out of reach of persons.

There is one detection cabinet per track for each direction of travel (Figure 4). Secondary measurement signals are evaluated there by railway-specific a.c. and d.c. protection devices; the trip signals are connected directly to fast transmission units. An additional PLC handles the disabling and acknowledgement signals; it also records detailed information on the operating status and provides this to the control centres for power supply network operation. Communication from each detection cabinet to the two substations takes place via “fast” as well as “slow” fibre-optic cable connections. The fast channels are used for direct transmission of trip, acknowledgement and ready signals, whilst the slow channels transmit the detailed status between stations, based on the protocol in accordance with IEC 60870-5-104 [8].

To increase operational availability, an indirect transmission path was set up in addition to direct transmission of trip commands from the track-side detection cabinets to the two substations. This runs between the substations and directly transmits any trip commands received to the respective substation; e.g. a trip signal received by the a.c. substation for the north track is sent to the d.c. substation. These direct and indirect transmission paths yield a 2-out-of-3 redundancy.

An interface cubicle is installed in each substation; this is the interface between the track-side detection cabinets and the circuit breakers along the route. Trip signals received via the fast fibre-optic channel are connected directly to potential-free terminals and fed to the circuit breaker tripping circuits. The trip signals are held internally until they are acknowledged. In the same way, the interface cubicles provide the connection between the substations and are the interface to the control centres.

In line with the operational concept, passage through the system separation section with a raised pantograph will lead to a switch-off of the power supply to the affected track from both sides but without affecting the opposite track. The power supply will remain disabled until the responsible operations control centre acknowledges the status; in the case of an a.c. voltage detection, this takes place in Utrecht at the central switching point for the AC 25 kV network. A d.c. detection is handled in Utrecht as well, by the central switching point for the DC 1 500 V network. In this way, disconnections resulting from improper passages can be dealt with differently to actual contact line faults. The contact line sections are not re-energized until all of the causes have been eliminated.

All in all, the goal of high functional reliability together with high operational availability demands a complex structure made up of trip commands, ready signals and acknowledgement signals.

Figure 4:
Track-side detection cabinet.

Figure 5:
Reaching the short-circuit zone while passing through the system separation section with voltage detection deactivated (Photo: ProRail).

8 Verification and testing

After completing assembling and factory testing of the individual cabinets and apparatuses, these were set up in the laboratory for a system test. This test included checking for correct sequences, detection sensitivity and system time. Here, it could already be seen that the system time remained significantly below the set time limit of 100 ms, even with start signals close to the trip thresholds and when the indirect transmission path was used.

The facility was erected by *ProRail* and step-by-step put into operation by RPS, which carried out an installation inspection as well as cabinet and system performance testing. At the end of June 2016 it was announced that the facility was ready for the acid test involving train runs.

The system testing performed by *ProRail* stipulated train runs from both power supply areas at different speeds and with different error scenarios. For the south track, which was operational first, system testing was performed in late July 2016 with the track completely closed to regular rail traffic.

For each direction of travel and each error scenario, the first run was made at a low speed of either 40 or 60 km/h, followed by a run at the maximum possible speed of 100 km/h due to the track closure. The scenarios tested were:

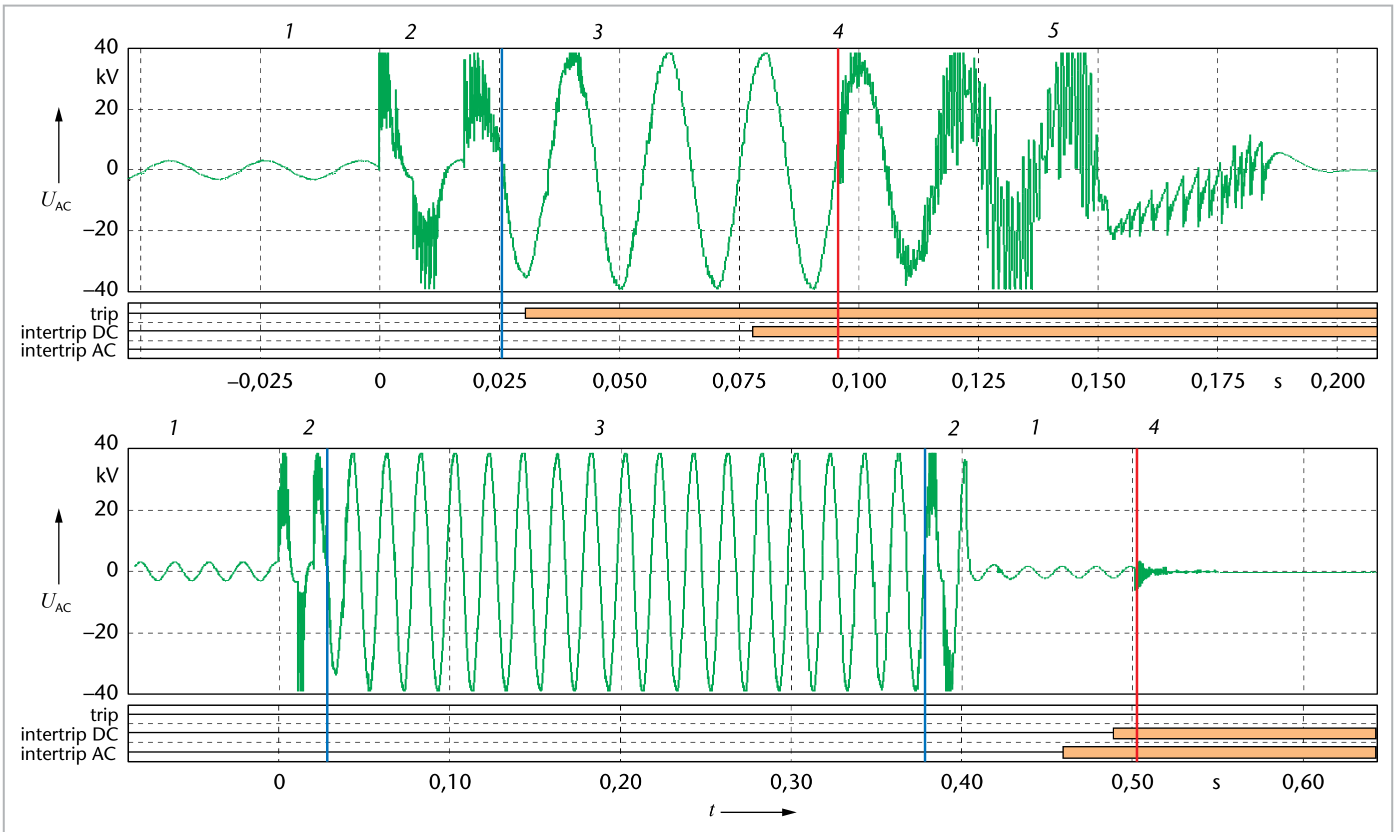


Figure 6:
Passing through the system separation section at 100 km/h, coming from a.c..

above with active voltage detection
below with deactivated voltage detection

1 Voltage interference
2 Passing through the section disconnector
3 Passing through the voltage detection zone
4 Switch-off of the supply
5 Re-initialisation of the vehicle current converter

trip From the trip signal generated by the voltage detector
intertrip DC Intertrip signal from the d.c. substation
intertrip AC Intertrip signal from the a.c. substation

- the required operating mode with a lowered pantograph, and
- the error scenarios:
  - pantograph not lowered
  - additionally: circuit breaker of a tractive unit switched on
  - additionally: main function "Voltage detection" switched off

As the system had not yet been tested in practice, the test trains only run on the system voltage of the overhead contact line, from which they entered the system separation section. Each following overhead contact line section in the direction of travel was neutral.

In order to monitor the system test, comprehensive data logging and transmission equipment was installed in the track-side detection cabinets, which could be remotely controlled from the a.c. substation. This made it possible to trace the curves of the a.c. and d.c. voltages as well as the chronology of the various trip signals.

As expected, the passage through the system separation section in the required operating mode with a lowered pantograph did not lead to a reaction. Likewise, the system responded as anticipated to each of the error scenarios:

- when the voltage detection was activated, it de-energized the contact line section before the train reaching the short-circuit zone, and
- when the voltage detection was deactivated, via the back-up function through the protection system in the feeding substation and intertripping in the other substation as well; Figure 5 shows the impacts of this type of undesirable passage.

Figure 6 shows an example of recorded voltage curves on the detection wire on the a.c. side. In-depth analysis of the measurement results revealed a larger number of details; thus,

- the a.c.-side voltage was already detected while passing through the upstream section disconnector,
- as anticipated, breaking small d.c. operating currents takes longer than 200 ms, quenching electric arcs in an open d.c. high-speed circuit breaker takes place as soon as the short-circuit zone is reached,
- particularly in the a.c. system, switching off the traction power supply as well as the continuing pulse patterns of the vehicle converter can be easily read out,
- loss of traction voltage caused by pantograph bouncing was only observed in the d.c. detection, lasted a maximum of 10 ms and had no identifiable effect on system behaviour,
- the passage speed could be reproduced from the signal curve by means of the length of the detection zone with a deviation of ±2 km/h.

By far the most significant result, however, was that the detection system reacted reliably in each test and at a higher speed than specified in the performance requirements. The typical system time for d.c. voltage detection was 35 ms and for a.c. voltage detection just under 60 ms, but never longer than 70 ms.

Following the successful test runs in both directions and with all error scenarios, the final run was made at 100 km/h with a raised pantograph leaving the d.c. system. Figure 7 shows this measurement.

The evaluation of the tests also showed a clear voltage interference to the detection wire in its newly constructed state. As an example, an induced voltage of 7 % of the nominal voltage was measured on the a.c. side. This confirmed the results of the system analyses and the necessity of the additional protective circuit that was implemented.

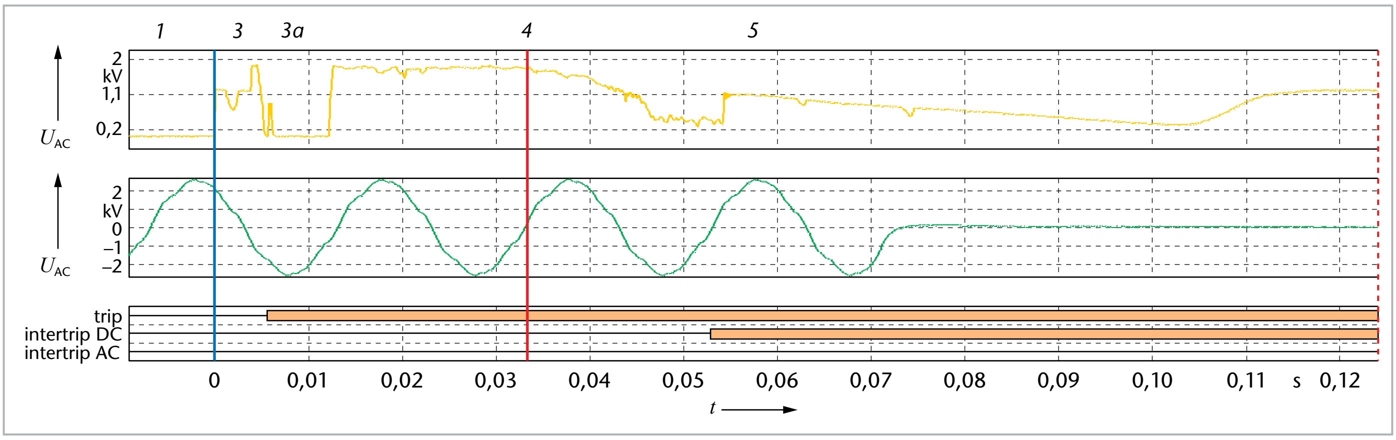


Figure 7:
Passing through the system separation section at 100 km/h, coming from d.c., final test run with both supply systems live.
1 ,*4*, *5*, trip, intertrip DC, intertrip AC see key, Figure 6
3a Contact interruption

9 Prospects

The scheduled and successful commissioning of the south track in July 2016 and the north track in October 2016 has made an efficient and safe power supply available for transnational rail traffic between the Netherlands and Germany.

Minor adjustments to the a.c.- and/or d.c.-side voltage detection are required for operation in the 1 AC 15 kV 16.7 Hz and DC 3 000 V railway power supply systems. Thus the concept of a system separation section based on a short neutral section with voltage detection can support cross-border rail traffic and in turn, help Europe continue to grow together.

Literature

[1] ProRail: OVS00054 from 01-05-2014 – Ontwerpvoorschrift Spanningssluis 25 kV – 1 500 V.

[2] Commission Regulation (EU) No 1301/2014 of 18 November 2014 on the technical specifications for interoperability relating to the “energy” subsystem of the rail system in the Union. In: Official Journal of the European Union L356 from 12.12.2014, pages 179–227.

[3] Commission Regulation (EU) No 1302/2014 of 18 November 2014 concerning a technical specification for interoperability relating to the “rolling stock – locomotives and passenger rolling stock” subsystem of the rail system in the European Union. In: Official Journal of the European Union L356 from 12.12.2014, pages 228–393.

[4] EN 50367:2012 + AC:2013 + A1:2016: Railway applications – Current collection systems – Technical criteria for the interaction between pantograph and overhead line (to achieve free access).

[5] EN 50388:2012 + AC:2012 Railway Applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability.

[6] *Keseljevic, Ch.; Courtois, Ch.; Aeberhard, M.*: System conversion from DC 1,5 kV to AC 25 kV 50 Hz. In Elektrische Bahnen 113 (2015), H. 6-7, pages 313–321.

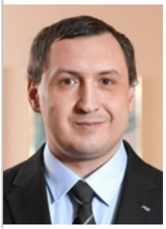
[7] *Mölke, U.; von Oppenkowski, F.*: System separation sections – in theory and in practice, instancing the system separation section at Horka. Speech at *acrps* 2015, Leipzig.

[8] IEC 60870-5-104:2006: Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles.

AUTHORS

Dipl.-Ing. Jens Northe (54), Studies of Electrical Power Engineering at TU Darmstadt; since 1989 Rail Power Systems GmbH respectively its legal predecessors ABB, Adtranz, Balfour Beatty Rail; various positions and tasks in the field of electrical traction power supply; since 2015 Senior Expert Rail Power Supply, dept. Systems Design.

Adress: Rail Power Systems GmbH,
Systems Design,
Frankfurter Straße 111,
63067 Offenbach, Germany;
Fon: +49 69 30859-535, Fax: -450;
E-Mail: jens.northe@rail-ps.com



Dr.-Ing. Andriy Zynovchenko (38), Degree in Industrial Energy Supply Systems at Pryazovskyi State Technical University in Mariupol, Ukraine; 2003 to 2006 research associate, subsequent promotion at Ulm University; since 2006 System Engineer in the Systems Design department at Rail Power Systems GmbH (till 2015: Balfour Beatty Rail GmbH).

Adress: see before;
Fon: +49 69 30859-384, Fax: -450;
E-Mail: andriy.zynovchenko@rail-ps.com

Richard Rieksen (60), Studies of Power Engineering and Electronics at Dutch Technical School; from 1986 to 1990 KEMA – testing engineer, thereafter KEMA/DNV GL Energy Advisory – Consultant and Rail System Engineer for ProRail.

Adress: DNV GL,
Department Substations,
Utrechtseweg 310,
6812AR, Arnhem, The Netherlands;
Fon: +31 26 3566080;
E-Mail: richard.rieksen@dnvgl.com

Ing. Jeroen Vonk (46), 1997 to 2010 Senior Project engineer Traction Energy Systems, Movares Nederland B.V; since 2010 Rail System Engineer, ProRail B.V.

Adress: ProRail, Department Projects,
HGB IV (De Inktpot),
Moreelsepark 3,
3511EP, Utrecht, The Netherlands;
Fon: +31 6 31792682;
E-Mail: jeroen.Vonk@prorail.nl

RPS/EN/426/0717

The specifications set out in this document apply to conventional applications. They do not represent performance limits. This means that divergent specifications may be attained in specific applications. The contractually agreed specifications alone shall apply. We reserve the right to effect technical modifications. TracFeed® is a registered trademark of Rail Power Systems GmbH.

RAIL POWER SYSTEMS GMBH

Garmischer Straße 35 | 81373 Munich | Germany | T +49 89 41999-0 | F +49 89 41999-270 | info@rail-ps.com | www.rail-ps.com