Report

Test: Digital Automatic Coupling

Phase II
Electric component
Final project report

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Change history

Version	Date	Changes	Author/Editor
1.0	30 May2023	Initial release	Florian Einsele/ Santiago Göpfert

Contents

1 List of abbreviations

Abbreviation	Meaning
DAC	Digital automatic coupler
DB AG	Deutsche Bahn AG
DBST	DB Systemtechnik GmbH
E coupler	Electric coupler, used for the transmission of voltages, information and signals
Common abbreviations are not explained in the list of abbreviations	

2 References

[1] Erprobung: Digitale Automatische Kupplung, Phase I, Elektrischer Teil (Test: Digital automatic coupler, phase I, electric part), DB Systemtechnik GmbH, 05.01.2022.

[2] DIN EN 60228:2005, Conductors of insulated cables (IEC 60228:2004); German version EN 60228:2005 + Corrigendum:2005.

[3] "TIS working group Digital Automatic Coupler (DAC) - Requirements for the electrical contacts in the coupling", 9 March 2020.

[4] DAC SPEC and Test Concept V1.01, 27.04.2020.

[5] DIN EN 50343:2014 Railway applications - Rolling stock - Rules for installation of cabling; German version EN 50343:2014.

[6] Erprobung: Digitale Automatische Kupplung, Phase II, Messtechnik (Test: Digital automatic coupler, phase II, measuring instruments), DB Systemtechnik GmbH, 22.03.2023

[7] Erprobung: Digitale Automatische Kupplung, Phase II, Prüfbericht Datenkommunikation (Test: Digital automatic coupler, phase II, test report on data communication), Owita GmbH, 22.03.2023

3 Order specification

In the test project for the digital automatic couplier (DAC) for freight wagons, DB Systemtechnik GmbH was commissioned to carry out electrical measurements to characterise the electric couplers. The conception and evaluation of the results was carried out by TT.TVE322, measurements by TT.TVP242.

This report includes the results of the electrical measurements carried out in the course of testing in Phase II. Testing involves resistance and insulation tests on DAC coupling points while at a standstill as well as the measurement of current and voltage during train movements during test operation.

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4 Measurement of contact resistances

In Test Phase II, the contact resistances of the supply and data cables were checked by measurement. The measurements took place between January and September 2022. To carry out the measurements, the supply and data cables of the coupled coupler pair in question were disconnected from the terminal boxes at both ends of the wagon and connected to the measuring equipment.

The contact resistances determined in this way include, in addition to the contact resistances at the contact point of the electric coupler, the resistance contributions of the power supply cables and contact resistances of the connections in the electric couplers. For a detailed discussion of this topic, please refer to Interim Report Electrical Part of Phase I [1]. The measuring instruments are described in the corresponding sub-report [6].

4.1 Power supply cables (110 V)

Figure 1 shows the contact resistances of the cables for the 110 V supply. Each measuring point on the abscissa corresponds to the measurement of all power supply cables of a coupled coupler pair. In the case of type A couplers, this corresponds to two measured values, one for the positive and one for the negative polarity of the supply voltage, while in the case of type B couplers, two cables of each polarity have been routed out separately, thus yielding four measured values per measurement. In total, the contact resistances were measured at ten type A and 20 type B coupling points.

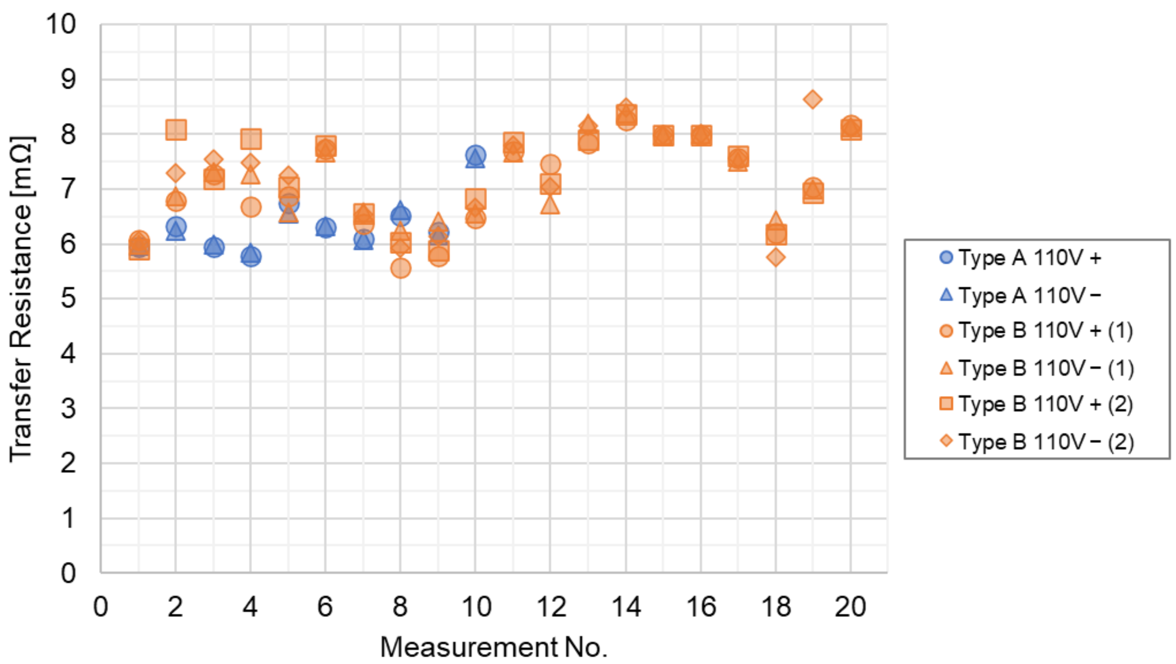

Figure 1: Contact resistances of the power supply cables (110 V)

Overall, the results for both coupler types show similar values with mean values of 6.34 mΩ (type A) and 7.21 mΩ (type B). The cross-sections of the power supply cables are 16 mm² in both cases. There is no clear trend over time that would indicate a degradation of the contact resistances in the electric couplers due to wear.

The resistance contribution of the supply cables is considerable: with a supply cable length per coupler of approx. 2.5 m, this amounts to approx. 6.2 mΩ (according to EN 60228:2005 [2], 16 mm² copper conductor cl. 5/6: 1.24 mΩ/m). It is therefore in the same value range as the overall determined contact resistance, including the contacts in the electric couplers. A detailed discussion of this issue can be found in [1].

Differences between the determined resistances are to a large extent due to different lengths of the power supply cables, depending on how they are routed on the wagon. However, individual measurements carried out at a single coupling point also show significant deviations, although the power supply cable length is identical in these cases. This is clearly visible, e.g. with coupler type B, measurement no. 2 and 4, and indicates a spread of the resistance value at individual coupling contacts.

4.2 Data cables

Figure 2 shows the contact resistances determined on the data cables of the same coupling points. With both types of couplers, four individual data cables are routed out, and therefore four measured values are obtained in each case. Again, ten type A and 20 type B coupling points were measured.

The mean value for coupler type A is 181 mΩ and for coupler type B 134 mΩ. The higher values for coupler type A can be attributed to a lower cable cross-section of 0.5 mm² compared to the cable cross-section of 0.75 mm² used for coupler type B. According to EN 60228:2005 [2], the length-dependent resistances are 40.1 mΩ/m (0.5 mm²) and 26.7 mΩ/m (0.75 mm²). With a total cable length of approx. 5.0 m, the calculated resistance contribution of the cables is 200.5 mΩ (0.5 mm²) or 133.5 mΩ (0.75 mm²). Deviating cable lengths and lower actual resistance values of the cables explain that the measured values including contact points in the couplers are on average even slightly lower.

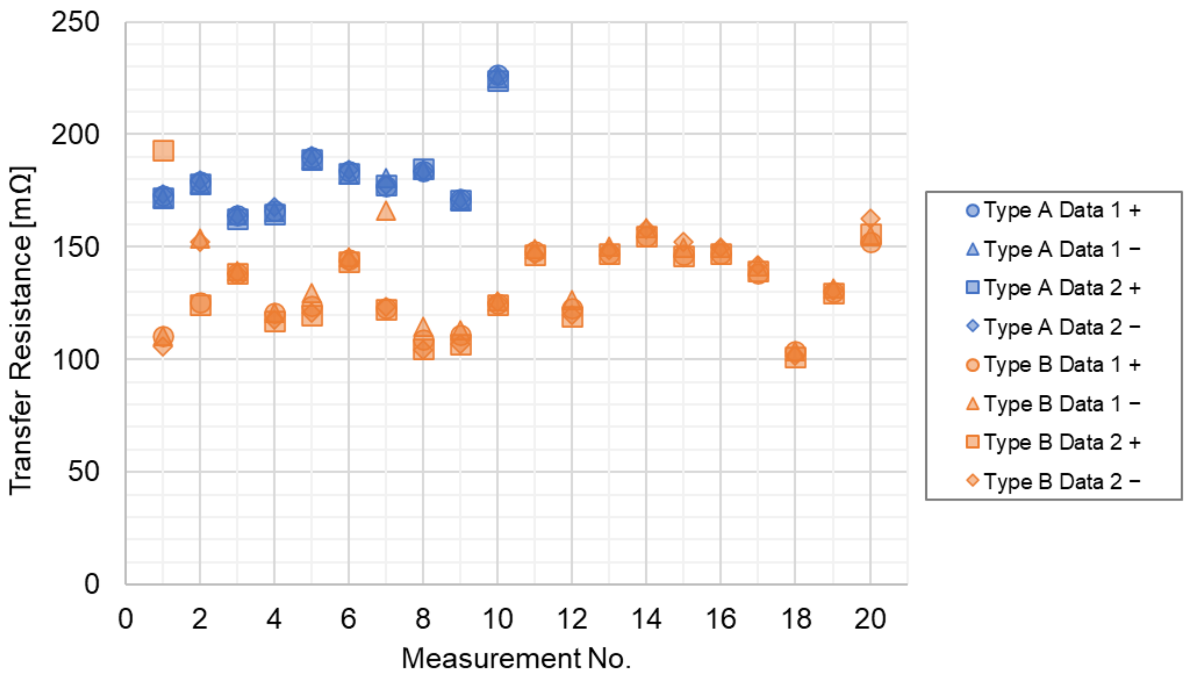

Figure 2: Contact resistances of the data cables.

Here, too, no clear trend is discernible over the course of the measurements during the test. The variations between the individual measurements show a course comparable to the resistance values of the supply cables in Figure 1, which are due to differences in the power supply cable lengths.

Likewise, a clear spread between the individual measured values is recognisable at individual coupling points, e.g. at coupler type B, measurements 2 and 7. Once again, coupler type A shows a more stable behaviour here. However, there are only half as many measured values for coupler type A as for coupler type B.

Supplementary note: The resistance value plays a rather subordinate role for data transmission. For the characterisation of the transmission parameters of the physical communication channel, please refer to the corresponding sub-report on data communication [7].

5 Insulation resistance measurement

In the course of measuring the contact resistances, the insulation resistances of the power supply cables and the control cables for the electro-pneumatic brake were also measured. The measurements were made against the earth potential of the electric couplers on the cables separated from the wagon circuits.

The measuring range end of the measuring device used is 3000 MΩ; see also the description in the corresponding sub-report [6]. For measurements indicating this value, the actual insulation resistance is thus 3000 MΩ or higher.

As an acceptance criterion for insulation resistance, a minimum value of 800 MΩ was specified in the requirements document of the TIS working group [3] and in the AUCO test specification [4] for a single electrical contact in an electric coupler. This value was derived from a consideration of a freight train consisting of 50 wagons and the parallel contributions to the total insulation resistance, which for worst-case scenario considerations should not exceed a value of 1 MΩ according to EN 50343:2014 [5]; see also [1].

5.1 Power supply cables (110 V)

Figure 3 shows the insulation resistances of the power supply cables. For coupler type A, ten measurements were carried out on the two connecting cables routed out; for coupler type B, 20 measurements were carried out on the four cables leading out separately. All measuring points carried out on coupler type A were at least 3000 MΩ (end of measuring range) and thus clearly above the specification value of 800 MΩ (In Figure 3, the values of measurements 5 to 10 are the same for both A and B.) For coupler type B, the majority of measuring points were also at 3000 MΩ (or above), but individual couplers have lower values.

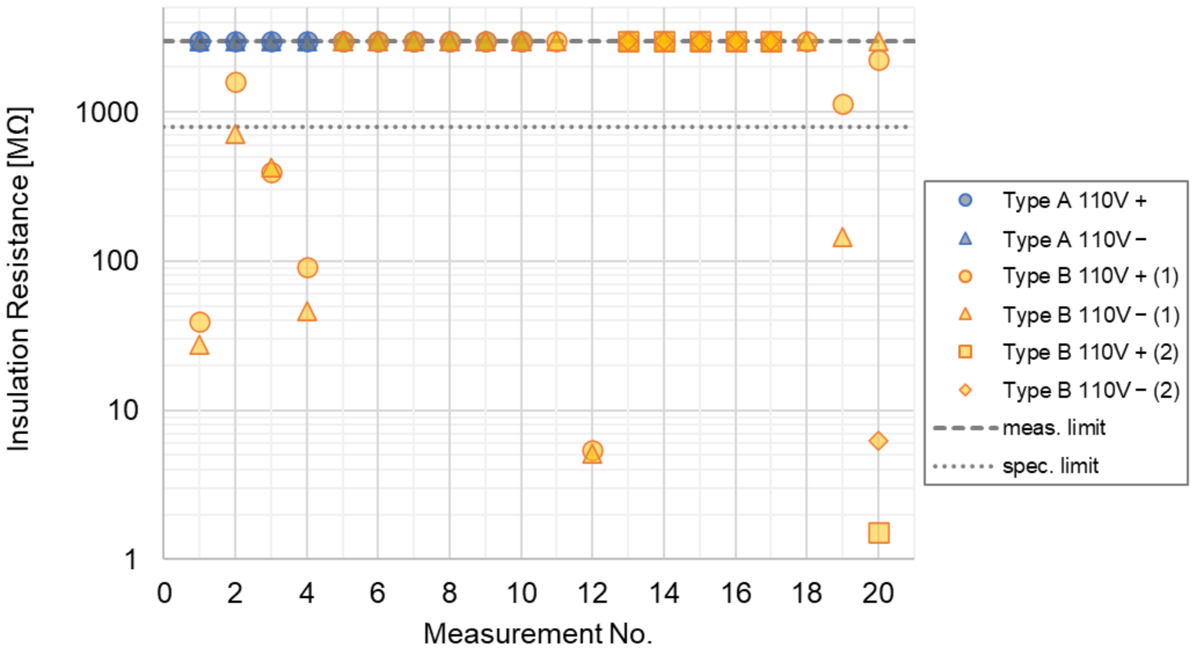

Figure 3: Insulation resistances of the power supply cables.

5.2 Control cables (ep brake)

The insulation resistances were also measured on the control cables for the electro-pneumatic brake "ep light", as these are also operated at 110 V. Figure 4 shows the results, which are similar to the results in Figure 3.

Again, coupler type A shows insulation resistances at least equal to the measuring device's range end of 3000 MΩ, while coupler type B shows some measured values below the specification value of 800 MΩ.

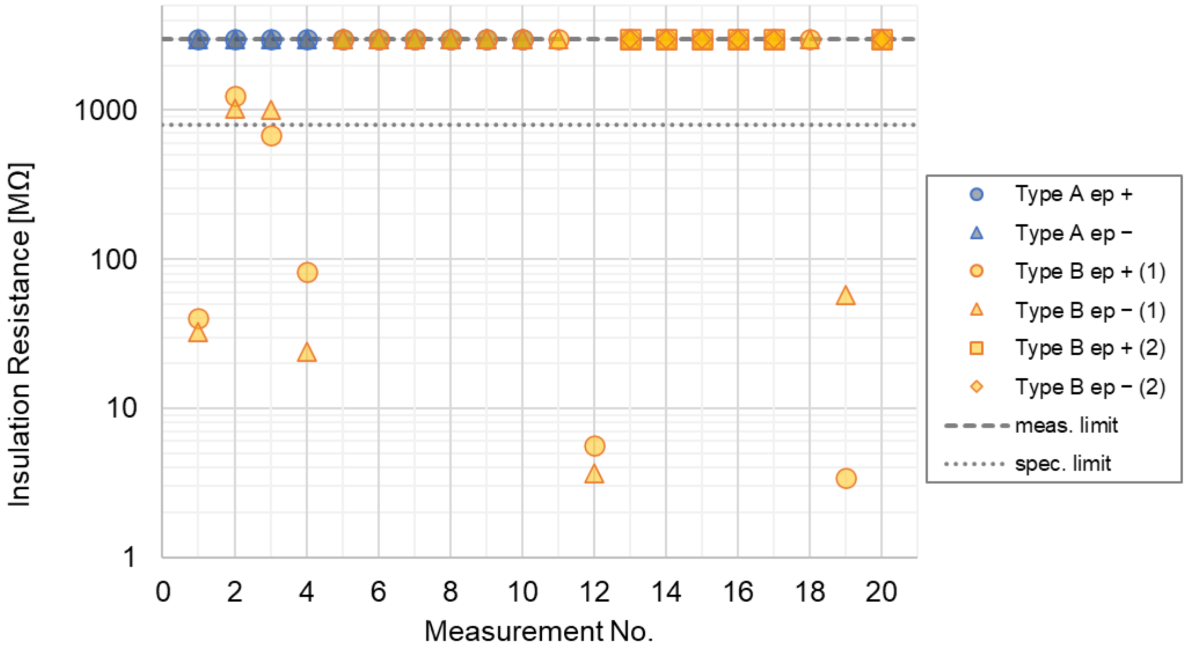

Figure 4: Insulation resistances of the control cables for the ep brake.

It is known that moisture, especially in combination with dirt, can considerably reduce the insulation resistance of contact points (plugs, couplers and the like) and that this resistance often increases again after the contact areas have dried. Since the measurements took place in different weather conditions, depending on the local conditions in a covered hall or outdoors, a weather-related influence on the results is basically conceivable.

In
Table 1, the spatial conditions (indoor measurement, outdoor measurements) and the weather conditions during the measurements are listed. The measurements on type A couplers all took place outdoors in dry weather, while five measurements (No. 3, 4, 12, 15, 16) on type B couplers were in damp weather. In some of these measurements (nos. 3, 4, 12) the insulation resistances were below the measuring end-of-range or specification limit, but not in all (nos. 15, 16). And there were also measurements with lower insulation resistances carried out in dry weather (nos. 1, 2, 19).

Overall, there is no clear correlation between weather and measurement results. It cannot be ruled out that residual moisture may still have been present during individual measurements due to previous condensation or humid weather, despite dry weather during the actual measurement.

Table 1: Date, location and weather conditions during the measurements

Type A				Type B							
No.	**Date**	**Loca-tion**	**Weather conditions**	**No.**	**Date**	**Loca-tion**	**Weather conditions**	**No.**	**Date**	**Loca-tion**	**Weather conditions**
1	12 March 2022	Outs-ide	Dry	1	26 January 2022	Inside	Dry	11	29 March 2022	Outs-ide	Dry
2	12 March 2022	Outs-ide	Dry	2	26 January 2022	Inside	Dry	12	30 March 2022	Outs-ide	Humid
3	12 March 2022	Outs-ide	Dry	3	27 January 2022	Outs-ide	Humid	13	6 September 2022	Outs-ide	Dry
4	29 March 2022	Outs-ide	Dry	4	27 January 2022	Outs-ide	Humid	14	6 September 2022	Outs-ide	Dry
5	29 March 2022	Outs-ide	Dry	5	12 March 2022	Outs-ide	Dry	15	6 September 2022	Outs-ide	Humid
6	29 March 2022	Outs-ide	Dry	6	12 March 2022	Outs-ide	Dry	16	6 September 2022	Outs-ide	Humid
7	5 September 2022	Outs-ide	Dry	7	12 March 2022	Outs-ide	Dry	17	7 September 2022	Outs-ide	Dry
8	5 September 2022	Outs-ide	Dry	8	12 March 2022	Outs-ide	Dry	18	7 September 2022	Outs-ide	Dry
9	5 September 2022	Outs-ide	Dry	9	29 March 2022	Outs-ide	Dry	19	7 September 2022	Outs-ide	Dry
10	5 September 2022	Outs-ide	Dry	10	29 March 2022	Outs-ide	Dry	20	7 September 2022	Outs-ide	Dry

6 Measurement of the power supply during test runs

During the test runs, the wagons are supplied with the 110 V supply voltage from a constant voltage source on the measurement wagon. The measurement wagon is located between the traction unit and the first wagon equipped with a DAC. The electrical connection is made at the DAC coupling points via the electric couplers, and at the wagons connected with screw couplers via a connecting cable. The latter concerns the coupling of the measurement wagon to the first wagon as well as the couplers between wagon-sets equipped with different DAC.

The supply voltage and the current on the power supply cable are continuously recorded at several selected points in the measurement train with a sampling frequency of 1200 Hz or with a temporal resolution of approx. 0.83 ms.

6.1 Measurement run without any particular irregularities

Figure 5 shows the temporal course of supply voltage (top) and supply current (bottom) during a typical measurement run.

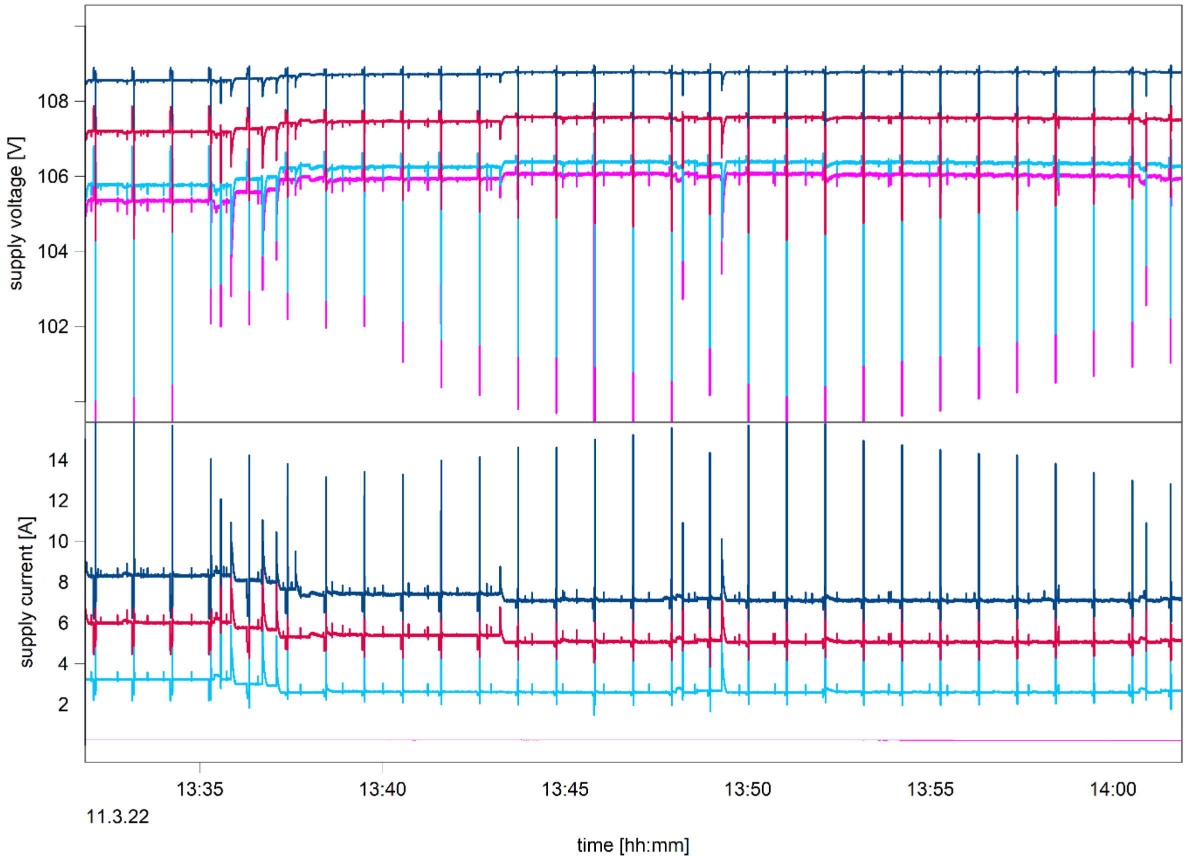

Figure 5: Supply voltage and supply current during a typical measurement run.

The supply voltage decreases due to the resistance losses in the cabling and at the couplers or plug connections from the supplying wagon to the last wagon (in Figure 5 this corresponds to the measuring records from top to bottom). Four channels for voltage and current are shown. The voltage difference between two measuring points is greater the more wagons there are between the measuring points.

The current at each measuring point is the sum of the partial currents of the wagons following the measuring point, taken from behind the measuring point, and therefore also decreases with increasing distance from the supplying measurement coach. At the last wagon, the measured supply current is zero. This measuring point is used for measurement in the event of a changed wagon sequence.

Supply voltage and current are constant over the measurement period of approx. 30 minutes for longer periods of time. The step-like changes in current and voltage are the result of changes in the consumer load, connection and disconnection processes and are therefore a typical and expected behaviour. Superimposed on this, a clear, time-synchronous deflection of the measured values is recognisable every 63 seconds on all measuring channels (current and voltage). Here, the voltage drops briefly and the currents rise briefly. This behaviour was already observed in Test Phase I and attributed to regular switching of the uninterruptible power supply units (UPS units) on the wagon. See also Section 6.3.3 in [1].

6.2 Measurement run with brief interruptions to the supply

Figure 6 shows the course of the supply voltage and supply current during another measurement run. Voltage and current show stable behaviour over the measurement period, which is again approx. 30 minutes, superimposed by the 63-second pulses of the UPS units. Their amplitude decreases with increasing measurement duration, which is probably due to a change in the state of charge of the UPS batteries.

In addition, dips in the supply voltage on the fourth channel (lowest voltage level, measuring point furthest away from the supplying measurement coach, shown in magenta in Figure 6) can be seen at irregular intervals.

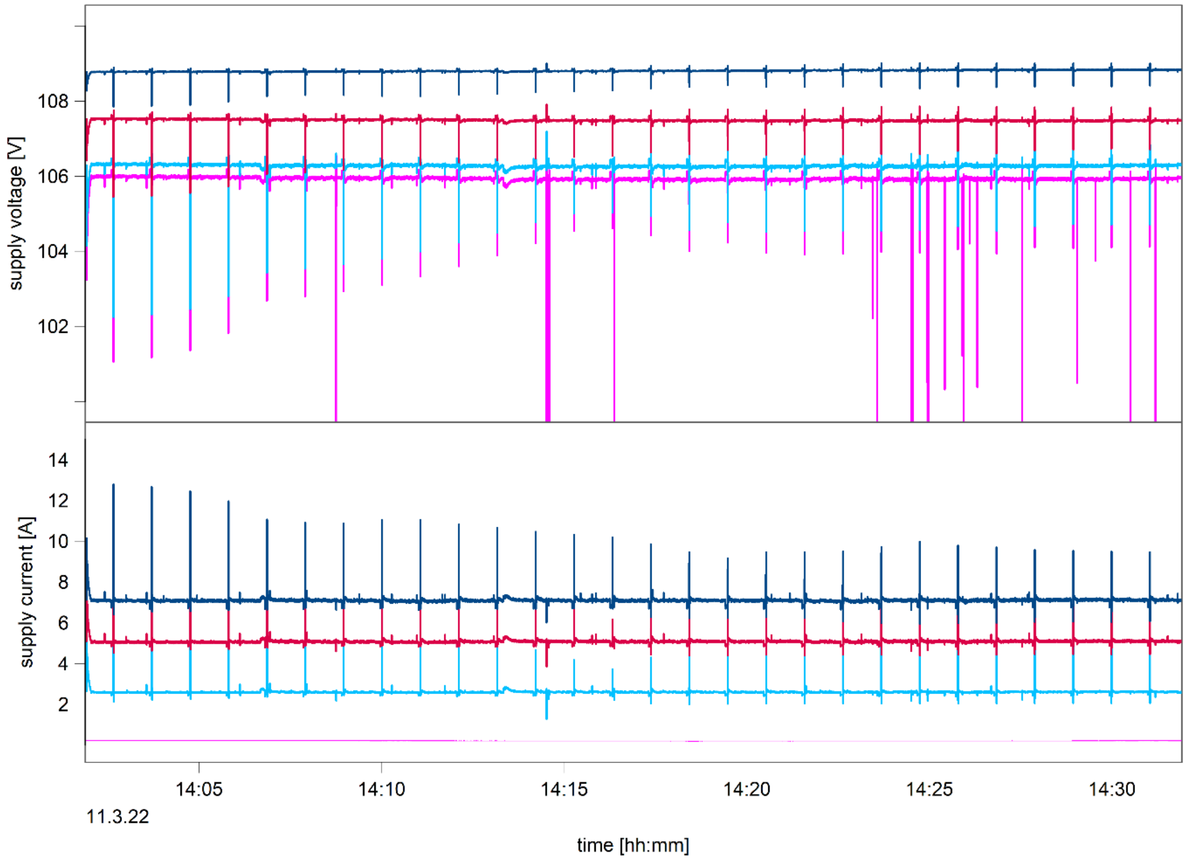

Figure 6: Supply voltage and supply current during a measurement run with interruptions in the supply

A closer look (Figure 7) shows that the voltage drops sharply and that the dips do not follow a regular pattern, unlike the 63-second pulses caused by the UPS units. Since dips are limited to the fourth and thus last channel (as seen from the measurement coach), the cause can be narrowed down to the area between the third and fourth measuring points. The behaviour indicates spontaneous interruptions of the supply circuit and it is possible – without ruling out other possible causes in principle – that it is a contact interruption at one of the electric couplers installed between the two measuring points.

The wagon consumers located behind the interruption point are not supplied during the interruption. This should be reflected in lower supply currents at the current measuring points further forward in the train.

Figure 8 shows a detailed view of one of the interruptions. The interruption duration is approx. 11 ms and the voltage drops to approx. 28 V. As expected, there is a slight drop in all three measured values on the current channels, presumably as a result of the load drop behind the interruption point. In the adjusted scaling of the voltage axis in Figure 9, an increase in the measured voltage values can be seen that is synchronous in time with the drop in the current values. This is understandable as a consequence of the reduced current and the associated lower conduction losses.

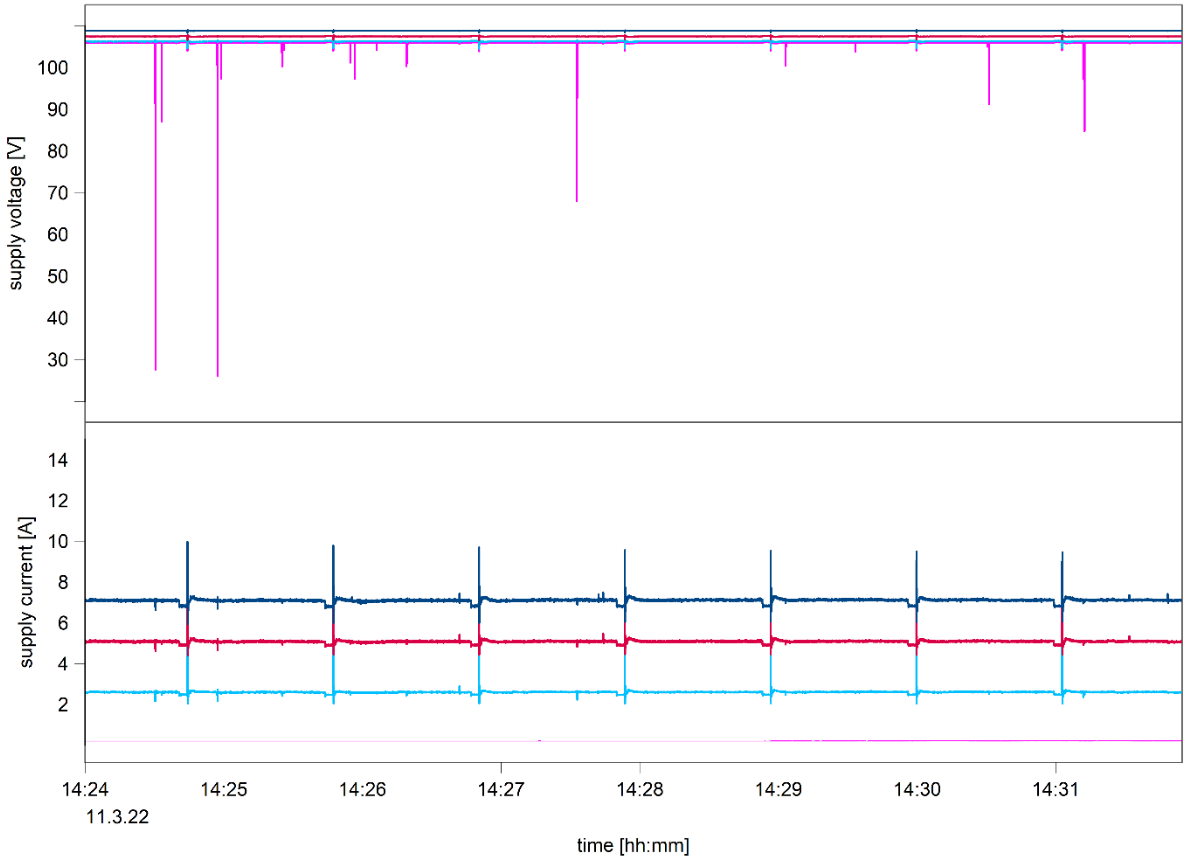

Figure 7: Measurement section with several interruptions of the supply

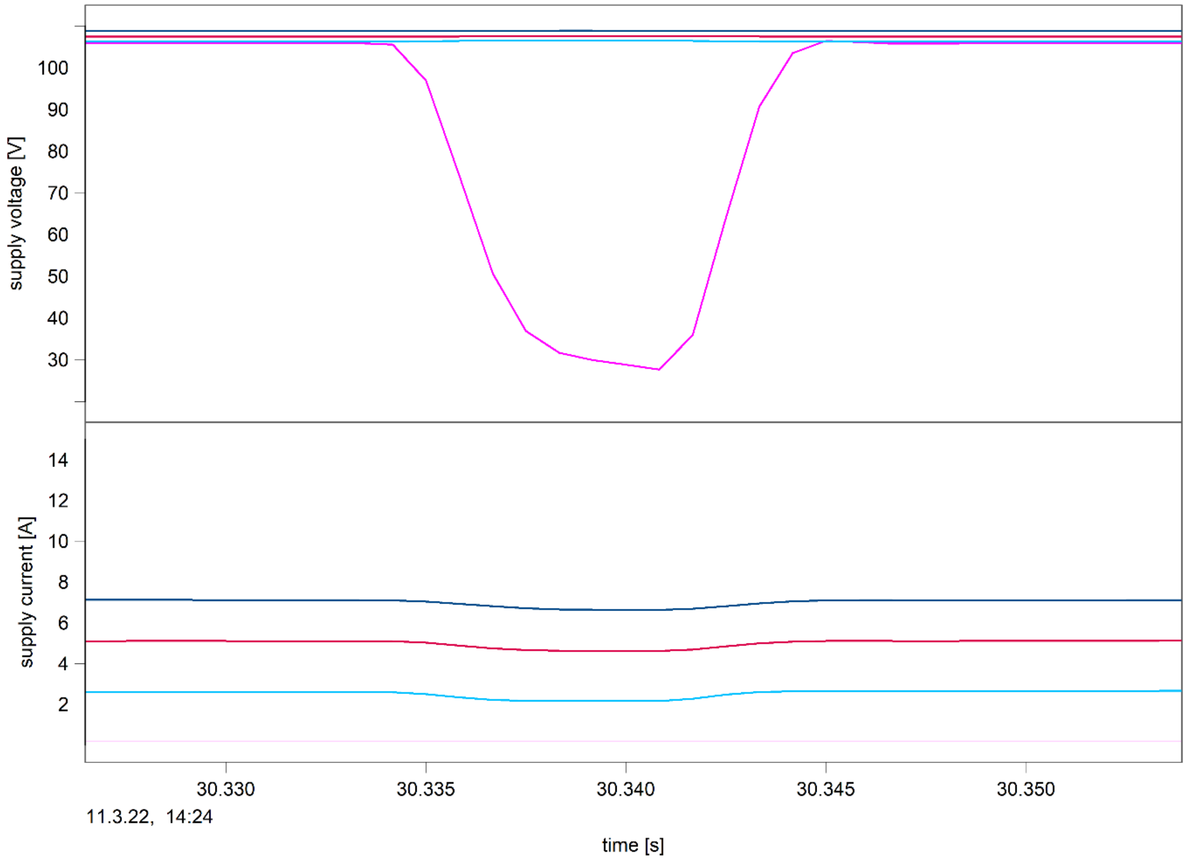

Figure 8: Detailed view of the voltage and current curve during an interruption.

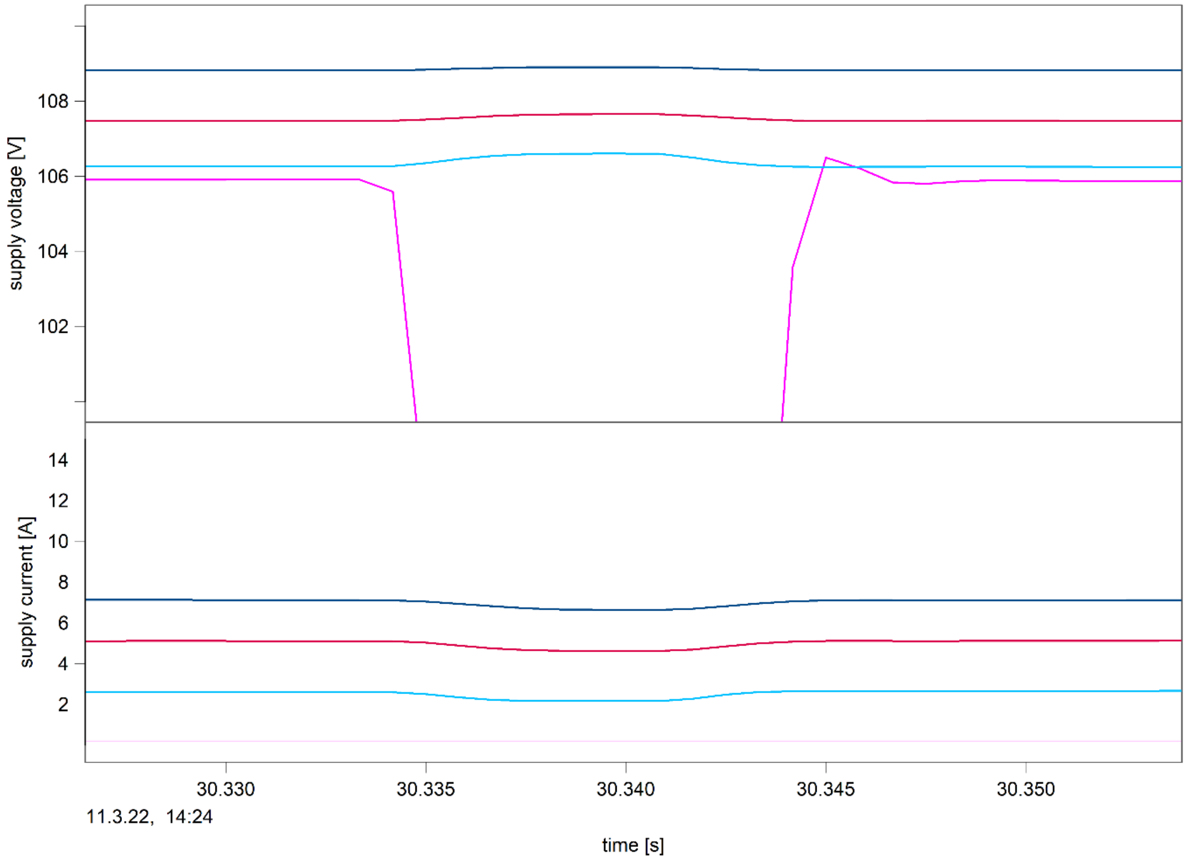

Figure 9: Time-synchronous behaviour of current and voltage during an interruption.

6.3 Statistical evaluation of contact interruptions

To quantify the interruptions, a ten-hour measurement run was automatically evaluated. Interruption was defined as voltage drops down to 90 V or below. The duration of the interruption was evaluated between falling and rising edge when passing through 90 V.

Figure 10 shows the distribution of occurrence of the interruptions determined from this, categorised into groups of 2 ms width. A total of 64 interruptions were registered with a mean interruption length of 5.87 ms (minimum 0.83 ms, maximum 15.8 ms). Converted to the run time of 10:05 h, a (registered) interruption took place on average approx. every 9.5 minutes.

The lower temporal limit of the interruptions coincides with the temporal resolution of the measurement of 0.83 ms (corresponds to 1200 Hz). It is therefore reasonable to assume that even shorter interruptions occur that were not detected by the measuring instruments used with the configured sampling frequency. It should be noted that the collection of measurement data over the period in question is a trade-off between sampling frequency and the amount of data recorded.

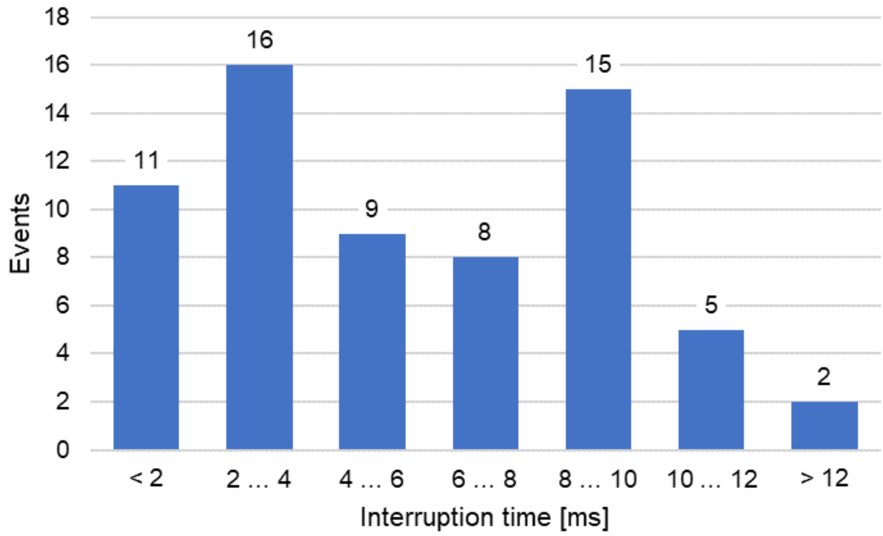

Figure 10: Distribution of occurrence of power supply interruptions during a measurement run

7 Summary and forecast

In Phase II, static measurements of the contact and insulation resistance were carried out on the DAC electric couplers, as well as measurements of the supply voltage and supply current during the test runs.

The contact resistances of the electric couplers – measured between the power supply and data cables of both coupling partners routed out – showed stable values for both types of couplers examined without degradation over time during the course of the test. The power supply cable resistance is the main influencing factor, while the resistances of the electric couplers and especially the contact resistances play a subordinate role.

In some measurements on type B electric couplers, the insulation resistance of the power supply cable and brake control cable fell below the minimum value set in the specification. A clear correlation between environmental conditions (especially humidity) and the measured values could not be established. The insulation resistances of the type A couplers showed values above the specification limit in all measurements.

The supply voltage and supply current were continuously recorded during measurement runs. During a measurement run, interruptions in the power supply between two measurement points were observed and subsequently evaluated. The recorded interruptions lasted between approx. 0.8 ms (resolution limit of the measurements) and approx. 15.8 ms and are presumably due to a single coupling point. The interruptions can have adverse effects on the durability of the electrical contacts (contact wear). Furthermore, the interruptions may possibly be the first signs of a permanent interruption if mechanical tolerances are the cause. Therefore, further tests were carried out on this topic, which are presented in the subreport on data communication.

8 Signatures

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--- End of report ---