1. Purpose and introduction

This document is based on and is consistent with the following documents:

- LOC&PAS TSI (published as an annex of EU 1302/2014 from 18th November 2014 and amended by EU 2018/868 from 13th June 2018),
- EN 50463:2017 (document from CENELEC, published in December 2017).

Both documents will be applicable to Energy Measuring Systems (EMS) installed on-board trains. This appendix E.3 presents the obligations regarding the new EMS on-board traction units running on the Infrabel network.

All equipment delivered must have undergone a "type test" in compliance with standard EN 50463. A "design review" which proves that the correct type of EMS equipment has been chosen for a specific type of traction unit is also compulsory. An "individual series test" of each piece of equipment must also be delivered.

If a check has already been carried out in another country about the correctness and completeness of these tests, then it is sufficient to provide us with the coordinates of this settlement responsible.

This document also indicates the possible solutions and conditions required to transmit the measurement data to Erex, the settlement solution of the international cooperation Eress, of which Infrabel is a member.

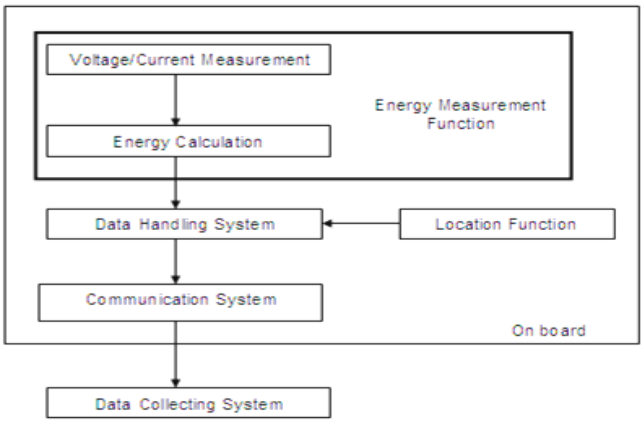
2. Energy Measuring System (EMS)

The on-board Energy Measuring System is the system for measurement of electric energy taken from or returned (during regenerative braking) to the contact line by the traction unit, supplied by the external electric traction system.

The functions of the system are the following:

- Energy Measurement Function (EMF), including voltage and current measurement and calculation of energy data ;
- Data Handling System (DHS), merging data from the EMF with time data and geographical position, producing and storing the Compiled Energy Billing Data (CEBD) ready to be sent by a communication system;
- Location Function, giving geographical position of the traction unit;

The above mentioned function elements may be performed by individual devices or may be combined in one or more integrated assemblies.



All requirements (environmental, mechanical, electric, supply, safety, marking, etc.) which the EMS and EMS components must meet are indicated in EN 50463-1. Particular attention must be paid to data security, not only regarding access but also data flow, including data export.

3. Energy Measurement Function (EMF)

3.1 Basic parameters

The EMF shall measure energy supplied by all electric traction systems for which the traction unit is designed.

The EMF shall be connected in such a way that all energy (traction, auxiliaries and comfort services) supplied to the train from the contact line and regenerated is recorded; for alternative current (AC) energy measuring system the reactive energy shall be recorded too.

The accuracy of EMF shall ensure that the total error is maximum 1,5% for AC for active energy and 2,0% for direct current (DC). This accuracy shall be determined in accordance with clause 0.

The elements used to implement the EMF are subject to legal metrological control, which shall be executed in accordance with the following:

- Accuracy of each element shall be tested under reference conditions according to clause 0, to verify that they are within their declared maximum error.
- Each element that complies shall be marked, to indicate metrological control and the declared maximum error limit.
- The configuration of each element shall be documented as a part of the metrological control.

3.2 Accuracies

3.2.1 Accuracy for active energy

The accuracy of EMF shall be determined in accordance with the following formula:

$$\varepsilon_{EMF} = \sqrt{\varepsilon_{VMF}^2 + \varepsilon_{CMF}^2 + \varepsilon_{ECF}^2}$$

Where:

- ε_{EMF} = total percentage error of EMF;
- ε_{VMF} = the maximum percentage error of the Voltage Measurement Function (VMF);
- ε_{CMF} = the maximum percentage error of the Current Measurement Function (CMF);
- ε_{ECF} = the maximum percentage error of the Energy Calculation Function (ECF).

The above mentioned maximum percentage errors of the individual functions shall be fulfilled under the following reference conditions:

- any voltage in between U_{min1} and U_{max2}, with U_{min1} and U_{max2} as defined in EN 50163:2004 clause 4.1, Table 1 (U_{max2} for 3 kV is 3900 V in accordance with corrigendum from 2013);
- any current in between 10% and 120% of the rated primary current of the EMF;
- frequency ±0,3% relating to the frequencies of the permitted traction supply systems;
- power factor in between 0.85 and 1;
- ambient temperature of 23°C ± 2°C.

3.2.2 Rated current

The rated primary current ($I_{n,EMF}$) shall be between 80 % and 120 % of the rated traction unit current. This rated traction unit current is defined as the maximum current that the traction unit is designed to take from the contact line when operating under normal conditions and with a voltage in the range from U_{min1} to U_{max2}.

If an EMF is designed to be used on more than one traction system it may have more than one value of rated primary current assigned. It is permitted to test the same EMF for different rated primary currents ($I_{n,EMF}$), in order to reduce the number of different types of EMF.

3.2.3 Accuracy class

The accuracy class and measurement errors authorised regarding discrepancies from the reference conditions mentioned above and for the voltage measurement function (VMF), the current measurement function (CMF) and the energy calculation function (ECF) are indicated in EN 50463-2.

3.2.4 Re-verification

The Manufacturer shall provide recommendations to the purchaser regarding any re-verification activities (testing and surveillance) that are considered necessary to ensure that the metrological performance of the functions making up the EMF can be expected to remain within the specified accuracies during the intended design life of the device containing these functions.

The recommendations shall be accompanied by supporting evidence (e.g. technical justification) to explain how ongoing metrological performance is ensured for the duration of the design life. The supporting evidence shall also indicate which aspects of the devices (making up the EMF) are relevant to ensuring the ongoing metrological performance perspective. The manufacturer shall clearly identify those aspects which require planned intervention (i.e. re-verification testing and surveillance) and those that do not.

3.3 Other requirements

All other requirements for the EMF are indicated in EN 50463-2.

The ECF must possess a storage register of energy data and quality flags. At least 60 days should pass until an index value can reach again its maximal value.

Other information may be recorded and transmitted to the DHS as long as this does not disrupt the processing of energy data or the compulsory indicators.

4. Système de traitement des données (Data Handling System - DHS)

4.1 Basic parameters

The DHS shall compile the measured energy data with other data without corrupting them. The DHS might be integrated in other equipment on-board of the traction unit.

The DHS shall incorporate a data storage with a memory capacity sufficient to store data of at least 60 days continuous work and consisting of consumed/regenerated active and reactive (if appropriate) energy, together with time reference and location data.

The Compiled Energy Billing Data (CEBD) shall be stored and transferred in chronological order according to the end times of each TRP and shall contain:

- unique unit number including the European vehicle number;
- end time of each elapsed measuring period for energy;
- the location data expressed in latitude and longitude at end of TRP;
- consumed/regenerated active and reactive (if appropriate) energy in each time period;
- quality flags for energy measurements and for location data.

Data from the DHS can be used for other purposes (e.g. feedback to the driver), provided that it can be demonstrated that the integrity data is not compromised by this arrangement.

4.2 Requirements

All requirements relating to the DHS are indicated in EN 50463-3.

If the clock is equipped with a dedicated battery, these batteries shall be replaced preventively at maximum two third of the expected life time of the battery.

Both the energy data and the location data must be accompanied by a quality flag.

The granularity of energy data is 0.1 kWh.

Location data used in the DHS shall be expressed as Longitude and Latitude. The format is degrees with 5 decimals.

If other values are available in the EMF, they shall also be transmitted, recorded and transferred to ground. Any data handling or communication linked to such data or activity shall not interfere with the flow and processing of data associated with CEBD.

The DHS must generate the data compiled for energy invoicing (*Compiled Energy Billing Data – CEBD*).

The DHS shall store data for the minimum period indicated below.

- software and system parameters: until replaced by authorised user;
- CEBD: 60 days;
- logfiles linked to CEBD production: 60 days;
- any other data: No minimum requirement.

4.3 Transferring CEBD from DHS to DCS

4.3.1 General requirements

The primary flow of data from the Data Handling System on-board (DHS) to Data Collecting Service on-ground (DCS) shall be the transmission of CEBD. CEBD contains measured values every 5 minutes. Infrabel also allows ReadingBlock to send samples every minute. All requirements for CEBD also apply to these Readings with minute values.

The DHS shall have a procedure for transfer of CEBD from DHS to DCS. The procedure shall at minimum include all CEBD not previously transferred to DCS. The procedure shall be automatically run minimum once per 24 hours, when EMS is fully operational. 95% of the full CEBD must be available the following day at 4:00. The DHS must also be able to carry out this procedure on demand by the DCS or all sources on board for this purpose, when the EMS is fully operational.

The CEBD shall be packed ready for secure transmission. All information necessary for the on-ground DCS to unpack the CEBD without corruption and store an authentic copy, shall be made available by the DHS supplier. The DHS supplier shall also make available the necessary information to allow the DCS to request CEBD from the onboard DHS where the DCS has missing or uncertain CEBD.

4.3.2 Consumption Point ID

The unique Consumption Point ID shall be based on the European Vehicle Number (EVN of 12 digits). A 13th number can be used to identify the different DHSs placed on the same vehicle. The extended ID is supplemented with the Vehicle Keeper Marking and a country code.

4.3.3 Data collection on ground

Infrabel is a member of the Eress partnership (www.eress.eu). The joint Erex application has already been used for the exchange, validation and allocation of the measurement data. From the beginning of 2019, Erex will also be able to receive measured values from EMS in accordance with the communication protocol included in the 2018 modified version of the LOC & PAS TSI.

This new communication protocol based on XML is mandatory for all new meters. Erex can receive both CEBDBlock (with measured values every 5 minutes) and ReadingBlock (with measured values every minute). For the time being, Erex will only be able to receive measured values via FTP. Further adjustments are planned. It is not yet clear which extra DCS functions will be added in Erex.

Railway Undertakings may also transmit this data to their own ground server. Existing DCS can also be kept. An audit by a third party must demonstrate that the data processing is correct.

The requirements on data security (EN 50463-1) are also applicable to all servers on-ground. This applies to intermediate ground servers and the real Data Collection Service on-ground. CEBD shall be transmitted to a DCS able to transmit the data in accordance with UIC-leaflet 930 (validation rules and UTILTS-data format) to a Data Distributor. This Data Distributor shall split the data in accordance with UIC-leaflet 930 (validation rules and UTILTS-data format) to a Settlement System.

UIC will publish a new IRS 90930 in 2019. This IRS will enable the usage of CEBDBlock and ReadingBlock (according to EN 50463: 2017 format) for data exchanges between servers on the ground. In time, they will replace the UTILTS data exchanges.

Any available data shall be sent at the latest at 5:00 on the next working day. This also applies when intermediate DCS are used.

All received CEBD will be validated and corrected by Infrabel before being applied for settlement and billing.

5. Conformity Assessment

Extra information is available in the Conformity Assessment Guidelines of Eress:

http://eress.eu/media/37588/conformity-assessment-guidelines-2017_web.pdf

If a verification of the conformity assessment has already been carried out in another country, then it is sufficient to provide us with the coordinates of the settlement responsible of that country.

5.1 Device level Design Review and Type Test

All equipment used fulfilling a part of the functions of the EMS, shall be subject of a conformity assessment. This conformity assessment consists of Design Review and a Type Test on a first item of the same series. The tests on equipment are stipulated in EN 50463-2 (EMF) and EN 50463-3 (DHS).

5.2 EMS Integration Design Review and Type Test

The integration design review demonstrates that all the devices of a specific equipment type used to form an EMS are able to be brought together correctly in accordance with an EMS design, and when integrated together provides the intended functionality.

The integration type test demonstrates that all the devices of a specific equipment type forming the EMS when integrated together are functioning as intended.

These tests shall be done by the integrator. If the EMS is ordered as a whole, it is the supplier's responsibility to carry out the tests, but they may also be carried out by the Railway Undertaking in case of retrofitting, or by the train builder in case of new rolling stock.

5.3 EMS Installation Design Review and Type Test

The installation design review assesses that the integrated EMS of a specific equipment type is compatible with the traction unit family and its functionality is maintained when installed on-board. It is important to check if the reference values of the equipment used are compatible with the types of traction units on which they are installed. Can the EMS accurately measure for all traction types on the locomotive or on the engine?

The installation type test demonstrates that the integrated EMS of a specific equipment type, when installed on-board on a specimen representative of the traction unit family, is functioning as intended.

The installer needs to deliver Maintenance Document. This document shall have all maintenance procedures and shall also describe all changes permitted on the equipment that can't effect the above mentioned requirements.

These tests are carried out by the installer. They may also be carried out by the railway undertaking in the case of installation at a later date, or by the train manufacturer in the case of new rolling stock.

5.4 Conformity Assessment Certificate

The assessor having the evidence of all previous Conformity Assessment shall produce the Conformity Assessment Certificate. This gives evidence that an EMS of a specific EMS equipment type can be installed on a traction unit of a specific traction unit family.

A test sheet to be used during EMS Installation Routine Testing shall be issued by the assessor.

5.5 Individual series test of the equipment

Each individual piece of equipment must pass the individual series test. The equipment tests are described in EN 50463-2 (EMF) and EN 50463-3 (DHS).

5.6 EMS Installation Routine Test

The installation routine test demonstrates that the type tested EMS functionality is assured for each installation on traction units of the same family. These installation routine tests consist of:

- Visual inspection: check if the EMS equipment type and the traction unit are in accordance with the related Conformity Assessment Certificate; check if EMS equipment type has been installed in accordance with the installation design and installation procedures; check the presence of device level routine test reports;
- Consumption Point ID: check consistency of Consumption Point ID with European Vehicle Number of the vehicle on which the EMS is mounted;

- Power-up: energize the power supply to the EMS and check the EMS reaches operational status;
- Power-down: initiate an intentional power down of the power supply used by the EMS and check the EMS has successfully powered down;
- Traction System change: apply the input signals to the EMS, check that traction system change is detected in accordance;
- Insulation: check that the insulation constrains and requirements identified during the installation design review are respected;
- Protection from non-authorised access: check that the measures for protection from non-authorised access identified during the installation design review are implemented and functioning;
- Indicator: check if the required indicators are functioning correctly;
- General safety requirements: check that any measures regarding the general safety requirements identified during the installation design review are correctly implemented;
- EMS data flow test: provide signals to each of the EMS inputs and check that all devices are functioning and CEBD is stored in the DHS; check that CEDB in the DHS is available through the local service port; initiate data export from the DHS to a DCS and check transfer is successful; check that the DHS is accessible from the DCS.

The EMS Installation Routine Test sheet shall be completed during this assessment.

5.7 Putting into service

To be able to receive data from an on-board EMS, the following information shall be transmitted to yourpower@infrabel.be.

For each new traction unit family:

- Name: e.g. locomotive type 18 or motor unit 80;
- Maximum power (in kW);
- Maximum speed (in km/h);
- Possible combinations: add names of other traction unit families that can be part of the same train, e.g. locomotive types 13 and 27 for the locomotive type 18.

A copy of the Conformity Assessment Certificates with a unique identification and the test reports used of all design reviews and type tests shall be transmitted to Infrabel.

For each new traction unit:

- European Vehicle Number for each vehicle;
- Short name previously used for the vehicle or traction unit (as painted on the train itself);
- Name of the traction unit family.

For each new EMS:

- Name of railway undertaking responsible for the maintenance of the energy meter;
- European Vehicle Number for the vehicle on which the EMS is mounted;
- Consumption ID of the EMS;
- A reference to the applicable Conformity Assessment Certificate;
- The completed EMS Installation Routine Test sheet.

5.8 Re-verification

To ensure that an in-service EMS can remain in operation it shall undergo a periodic re-verification according to next procedure. The periodic re-verification procedure shall include:

- verification of any part of the EMF requiring periodic testing (check of the metrological characteristics, in accordance with the conditions agreed with the competent authorities, taking into account the information provided in 3.2.4);
- inspections designed to ensure that the type of EMS equipment fitted on the traction unit corresponds to the type of EMS equipment requested as described in the documentation;
- in the case of presence of physical protections (such as lead seals), a check that they are actually present.