Správa železniční dopravní cesty

Railway Infrastructure Administration, state organization
Czech Republic

Eress Forum 2016

Energy metering in trains in the Czech Republic

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Správa železniční dopravní cesty

General information

As of 01/01/2013, following the Transformation Act No.77/2002 Coll., two organizations - Czech Railways, joint-stock company, and Railway Infrastructure Administration, state organization (SZDC) - were established.

- SZDC has taken over the management of state assets mainly represented by the railway infrastructure.
- We fulfil the role of a rail owner, providing operation, operability, modernization and development of the railway infrastructure.
- We allocate the path capacity, ensuring equal access for all carriers.
- As of 01/07/2008 we have also become the operator of the national and regional rail systems owned by the Czech Republic.
- Since 01/09/2011 we have been ensuring rail maintenance and operation control in the Czech Republic.

Správa železniční dopravní cesty

Basic characteristics of the rail network

Total length of lines	9,470 km
Total length of electrified lines	3,208 km
Total length of tracks	15,552 km
Rail network density	122 m/km^2
Railway crossings	8,096
Interoperable parameters of transit corridors	
Gauge	1,435 mm
Structure gauge	UIC-GC
Loading gauge (Track carrying capacity)	UIC-D4
Contact line systems	AC 25 kV/DC 3 kV

Správa železniční dopravní cesty

Energy structure

Number of AC Traction Substations	28
Number of DC Traction Substations	61
Consumption per year	1 185 GWh
Of which DC	852 GWh
AC	333 GWh
Electric locomotives 	1015
Measured locomotives (EMS)	90
Ground system (DCS)	basic functions
Settlement system	measured values not used

Správa železniční dopravní cesty

Energy background SZDC

- License of Distribution electricity
- License of Trade with electricity (non traction energy)
- Trading/distribution unit SZDC (approx. 150 employees)
  - Railway Energy Administration in Hradec Králové
- Software SAP IS-U
  - Remote reading of electrometers
  - Database of consumers
  - Groups of consumers,
  - Calculation of consumption
  - Data hang over to OTE - Czech electricity and gas market operator
  - Prepared for measured data from trains

Správa železniční dopravní cesty

Unknown or unsure

1. Lack of legislation
   - Public energy sector x railway energy sector (72/2009)
   - UIC 930 – not binding
   - EN 50 463 1.-5. – not binding yet

2. Cost of installation x cost of operation x cost of energy
   - Main motivation for train operators

3. Expectation
   - Open market
   - Full liberalization = every train operator chooses its energy trader (better price = saves money)
   - Manager of infrastructure controls conditions (distribution network with open access)
     - Recuperation during braking
     - Returning energy (unpredictable, very low price)
     - Losses in substations and OCL

4. Energy market
   - Generally liberalized in EU, but not in railway sector from the viewpoint of energy
   - Different approach from energy and railway (interstate legislation can not solve it separately)

Správa železniční dopravní cesty

Possible ways

- **Closed railway energy market, nothing measured**

  Open energy market:

  Consumer is a manager of infrastructure

  Closed railway energy „market“:

  - ❑ Consumption of train operators is divided according to agreed rules
  - ❑ All losses in substations and OCL are accounted for

- **Closed railway energy market, measured for non-energy purposes**

  Open energy market:

  Consumer or another entity is a manager of infrastructure

  Closed railway energy „market“:

  - ❑ Consumption of train operators is calculated according to agreed rules using measured data (useful for improvement of energy consumption efficiency – good for train operators)
  - ❑ All losses in substations and OCL are accounted for.

- **Open railway energy market**

  Open energy market/liberalised railway energy market:

  Consumer is a railway operator and also manager of infrastructure

  - ❑ Consumption of train operators is calculated by software with respect to energy price (contracted with trader) and distribution fees (regulated by market regulator)
  - ❑ All losses in substations and OCL are accounted for and reflected in distribution fees.

Specification of measurement standards – 2012

A measurement concept was prepared in the Czech Republic

- Infrastructure Operator Instructions PPD_4_2012 were prepared
- Distribution of deliveries OPERATOR / POWER INFRASTRUCTURE ADMINISTRATOR was specified

Správa železniční dopravní cesty

Present time

Access to the railway infrastructure

- SZDC provides access to the rail network, including traction electricity distribution.
- The owners (locomotive operators – railway companies) are legally separate companies (e.g. Czech Railways, ČD Cargo, Metrans etc.)

Settlement traction consuption

- Currently invoicing of traction consumption is carried out on the basis of records of traffic operations [Gross-tonne-kilometres, grtkm] and specific consumption [kWh/grtkm] specified for individual types of trains.

Správa železniční dopravní cesty

Present time

SZDC has accepted the role of provider of measured data in the Czech Republic. It is therefore responsible for the measurement of traction energy in the Czech Republic and therefore it carries out the following roles:

- data collector
- measured data distributor
- entity responsible for the data
- entity responsible for deviations
- measured data aggregator

Správa železniční dopravní cesty

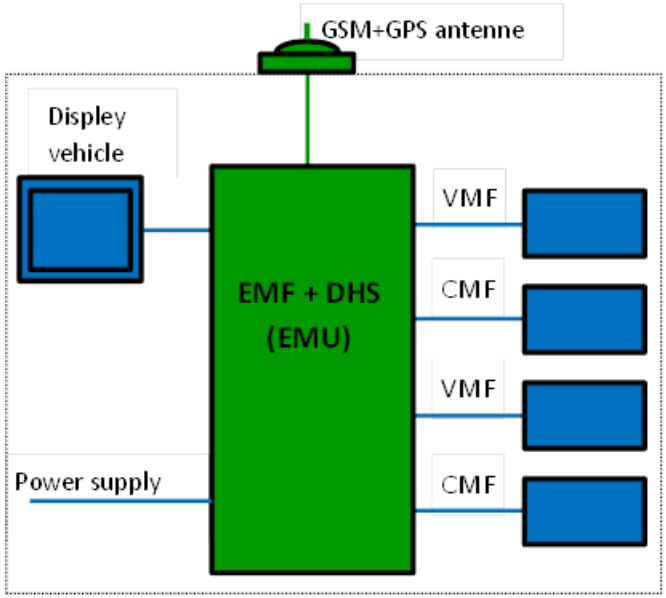
Present time

Property relations in the measurement system on board

- SZDC owns Measuring Boxes.
- SZDC installs them in the vehicles of railway operators (owner, operator)
- Meanwhile we not charge rental payments of measuring box

Specification of measurement standards – 2012

EMS diagram



Legend:

- Parts of EMS, provided by the owner of a rail traction vehicle
- Parts of EMS, provided by infrastructure power manager (SZDC)

Správa železniční dopravní cesty

The basic required standards of a measurement system

- DC sensors and AC measuring transformers must be used for consumption measurement purposes **only**
- Compliance with the overall accuracy of the measuring system according to the requirements of the standard EN 50 463
- Before mounting in rail vehicles, reports of authorized testing laboratories must be submitted
  - ✓ Calibration report of the meter for DC signal
  - ✓ Test report of the meter as a legally controlled meter for measuring AC 50 Hz
  - ✓ Calibration report of DC current and voltage sensors
  - ✓ Test report of legally controlled meter for AC 50 Hz (AC 16 2/3 Hz) current and voltage measuring transformers.
- Use of inductive measuring transformers is required.

Správa železniční dopravní cesty

The basic required standards of a measurement system

- Data transfer preferably in own GSM-R network (SZDC)
- it is also possible to use public GSM networks with roaming enabled in the network of other GSM public operators.

Správa železniční dopravní cesty

Specification of measurement standards – 2012

- Requirements for AC/DC traction measurement were specified
- Requirements were based on EN 50 463, EN 50 470-1-3, measurement acc. to MID and valid standards for invoicing measurement in the Czech Republic
- Requirements for voltage measurement transformers and current converters for AC systems, and DC voltage and current sensors were specified
  - GSEFB 25F voltages transformer and UGSS 710 current converter with 0.5 accuracy by Ritz were selected for AC system
  - for DC systems, DV4200 and LF2005 sensors were selected by LEM
- Structure of data to be sent was specified

Správa železniční dopravní cesty

Specification of measurement standards – 2012

- The Tender for 80 measurement boxes including vehicle installation was launched.
- UniControls a.s. won the contract with the WATTMET-3/A measuring box, which contains the ELM-101 electrometer and communication unit TLR-2 for transfer of data to DCS.
- Data in CEBD format in ABL file are send to the ground server SZDC.

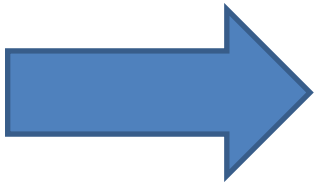
Description of ABL format at EMS

Description of meter data

Filename: Meter_1300010000000_00006172_1407180345.ABL

Parts of the file

[HEADER]
PROT = 0.10
LBL1 = makro1
MAN1 = UNi
DEV1 = 950206
ZNR1 = 130001
DATE = 180714
TIME = 034500



Header:
PROT…version FW TLR2
LBL1…configuration of the EMS lable (defined in TLR2 Web console)
MAN1 … manufacturer ident
DEV1 … serial number of the ELM101
ZNR1 …TPID - (EMS identification)
DATE … date of last record
TIME … time of last record

Description of ABL format

[ELM-DATA]
1.0.99.1.0.255(22)
(0.0.1.0.1.255)()
(0.0.1.0.0.255)()
(1.0.96.5.1.255)()
(1.0.0.8.4.255)()
(1.0.1.8.0.255)(MWh)
(1.0.2.8.0.255)(MWh)
(1.0.3.8.0.255)(Mvarh)
(1.0.4.8.0.255)(Mvarh)
(1.2.5.8.0.255)(Mvarh)
(1.2.6.8.0.255)(Mvarh)
(1.2.7.8.0.255)(Mvarh)
(1.2.8.8.0.255)(Mvarh)
(1.1.1.8.0.255)(MWh)
(1.1.2.8.0.255)(MWh)

(1.0.1.15.0.255)(MW)
(1.0.21.6.0.255)(MW)
(1.0.22.6.0.255)(MW)
(1.0.11.6.0.255)(kA)
(1.0.12.6.0.255)(kV)
(1.0.12.3.0.255)(kV)
(1.0.128.0.0.255)(Hz)
(1.0.129.0.0.255)(Hz)

The list of items in CEBD blocks

We use and prefer index values as opposed delta values.

Description of ABL format - record

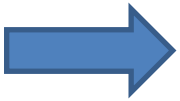
Správa železniční dopravní cesty

Variable number of CEBD block, in this example 7 blocks

(034100)(20140718)(00000000)(1)(002352.585)(000005.383)(000326.070)(000058.319)(000319.206)(000006.864)(000002.710)(000055.609)(001657.586)(000001.474)(00000.123)(00001.666)(00000.000)(000.065)(026.919)(026.545)(50)()

(034200)(20140718)(00000000)(1)(002352.608)(000005.383)(000326.076)(000058.319)(000319.212)(000006.864)(000002.710)(000055.609)(001657.586)(000001.474)(00000.123)(00003.177)(00000.000)(000.122)(026.814)(013.030)()(16)

[CRC]
*3a76



CRC… … CRC16 of all the characters from beginning of the file to the character “*“

Správa železniční dopravní cesty

ELM-DATA Description

ELM-DATA Description:

1.0.99.1.0.255(22)	VALUE_LOAD_PROFILE ... number of values transmitted in one CEBD block
(0.0.1.0.1.255) ()	VALUE_TIME ... time of the measurement, format hhmmss
(0.0.1.0.0.255) ()	VALUE_DATE ... date of the measurement, format yyyymmdd
(1.0.96.5.1.255) ()	VALUE_STATUS_WORD ... Status Word the list of implemented status codes listed in chapter 3
(1.0.0.8.4.255) ()	VALUE_RECORDING_INTERVAL_MINUTES ... length of the measurement interval in minutes
(1.0.1.8.0.255) (MWh)	VALUE_ACTIVE_ENERGY_POSITIVE ... Overall consumed active energy +A
(1.0.2.8.0.255) (MWh)	VALUE_ACTIVE_ENERGY_NEGATIVE ... Overall generated active energy -A
(1.0.3.8.0.255) (Mvarh)	VALUE_REACTIVE_ENERGY_POSITIVE ... Overall consumed reactive energy +R
(1.0.4.8.0.255) (Mvarh)	VALUE_REACTIVE_ENERGY_NEGATIVE ... Overall generated reactive energy -R
(1.1.1.8.0.255) (MWh)	VALUE_ACTIVE_ENERGY_POSITIVE_DC... Overall consumed energy in DC network
(1.1.2.8.0.255) (MWh)	VALUE_ACTIVE_ENERGY_NEGATIVE_DC... Overall generated energy in DC network
(1.0.1.15.0.255) (MW)	VALUE_LAST_FIFTEEN_MINUTE_ACTIVE_POWER... Fifteen-minute moving average of the active energy
(1.0.21.6.0.255) (MW)	VALUE_MAX_ACTIVE_POWER_POSITIVE...Max active power consumed during measurement interval
(1.0.22.6.0.255) (MW)	VALUE_MAX_ACTIVE_POWER_NEGATIVE...Max active power generated during measurement interval
(1.0.11.6.0.255) (kA)	VALUE_MAX_CURRENT... Max RMS current during measurement interval
(1.0.12.6.0.255) (kV)	VALUE_MAX_VOLTAGE... Max RMS voltage during measurement interval
(1.0.12.3.0.255) (kV)	VALUE_MIN_VOLTAGE... Min RMS voltage during measurement interval
(1.0.128.0.0.255) (Hz)	VALUE_FREQUENCY_50 ... presence of the 50Hz network
(1.0.129.0.0.255) (Hz)	VALUE_FREQUENCY_16 ... presence of the 16,7Hz network

Správa železniční dopravní cesty

First CEBD block values interpretation

(034100)	Time of the measurement is 03:41:00
(20140718)	Date of the measurement is 18 of July 2014
(00000000)	Status is No event
(1)	Length of the measurement interval is 1 minute
(002352.585)	Overall consumed active energy is 2352.585 MWh
(000005.383)	Overall generated active energy is 5.383 MWh
(000326.070)	Overall consumed reactive energy is 326.070 Mvarh
(000058.319)	Overall generated reactive energy is 58.319 Mvarh
(000319.206)	Overall consumed reactive energy inductive is 319.206 Mvarh
(000006.864)	Overall consumed reactive energy capacitive is 6.864Mvarh
(000002.710)	Overall generated reactive energy inductive is 2.710Mvarh
(000055.609)	Overall generated reactive energy capacitive is 55.609Mvarh
(001657.586)	Overall consumed energy in DC network is 1657.586MW
(000001.474)	Overall generated energy in DC network is 1.474MW
(00000.123)	Fifteen-minute moving average of the active energy was 123kW
(00001.666)	Max active power consumed during measurement interval was 1.666MW
(00000.000)	Max active power generated during measurement interval was 0W
(000.065)	Max RMS current during measurement interval was 65A
(026.919)	Max RMS voltage during measurement interval was 26.919kV
(026.545)	Min RMS voltage during measurement interval was 26.545kV
(50)	50Hz network detected
()	16,7Hz network not detected

Správa železniční dopravní cesty

Description of GPS data

Filename: GPS_1300010000000_00006172_1407180345.ABL

Parts of the file

```
[HEADER]
ZNR1 = 1300010000000
DATE = 180714
TIME = 034500

[GPS-DATA]
$GPRMC,034100,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*07
$GPRMC,034200,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*04
$GPRMC,034200,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*04
$GPRMC,034227,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*01
$GPRMC,034300,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*05
$GPRMC,034400,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*02
$GPRMC,034500,V,0000.0000,N,00000.0000,E,000.0,000.0,180714,,*03

[CRC]
*b4f8
```

Header:
ZNR1 ...TPID - (EMS identification)
DATE ... date of last recodr
TIME ... time of last record

Variable number of NMEA $GPRMC sentences related to CEBD blocks , in this example 7 blocks
format description at
http://aprs.gids.nl/nmea/#rmc

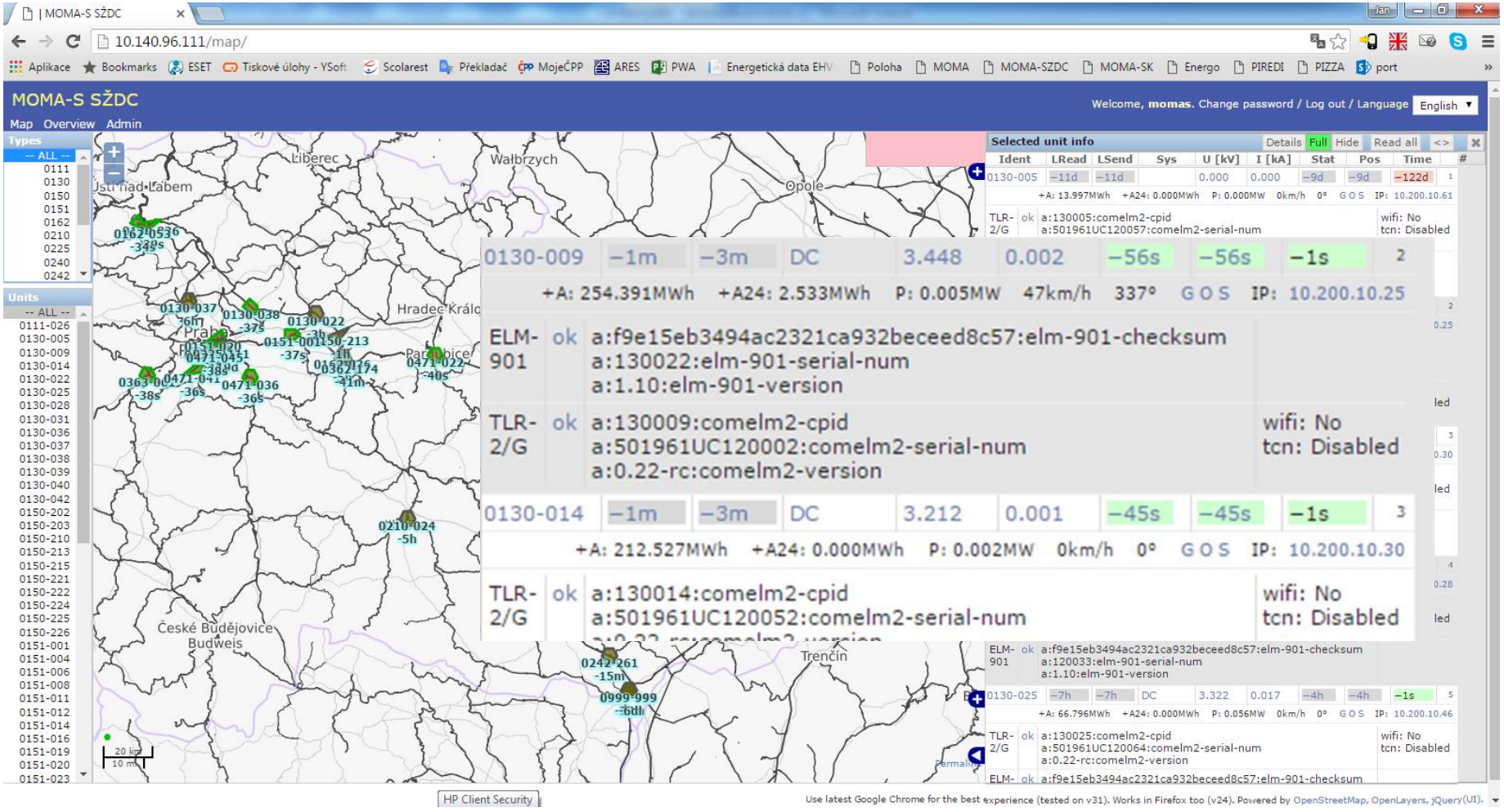
CRC... CRC16 of all the characters from beginning of the file to the character "*"

DCS – ground server SZDC

- The SZDC ground server checks the data received
- After the check, the data are processed into the database
- The data are further used to check vehicle consumption and its efficiency
- Comparison of demand and energy consumption of the same type of trains
- A pilot project for invoicing, according to the measured values, has started
- Comparison of flat-rate invoicing / invoicing of measured consumption
- Data are monitored by the management of carriers, who use the data to assess train driver efficiency

Správa železniční dopravní cesty

Visualisation using MOMA server



Správa železniční dopravní cesty

Implemented measuring

VEHICLE	CUSTOMER	QUANTITY	PERIOD	
Class 111 DC	ČD Cargo	1	2016	
Class 130 DC	ČD Cargo	9	2012 - 2016	
Class 150 DC	ČD – Czech Railways	10	2012 - 2013	
Class 151 DC	ČD – Czech Railways	12	2012 - 2013	
Class 162 DC	ČD – Czech Railways	2	2012 - 2013	
Class 460 DC	ČD – Czech Railways	2	2012 – 2013	

Správa železniční dopravní cesty

Implemented measuring

VEHICLE	CUSTOMER	QUANTITY	PERIOD	
Class 471 DC	ČD – Czech Railways	6	2012 – 2013	
Class 230 AC	ČD Cargo	20	2010 – 2011	
Class 240 AC	ČD Cargo	5	2012 – 2016	
Class 242 AC	ČD – Czech Railways	9	2012 – 2013	
Class 363,362 DC + AC	ČD, ČD Cargo	5	2012 – 2016	
Class 680 DC + AC	ČD – Czech Railways	2	2012 – 2013	

Správa železniční dopravní cesty

ELC-201 New type of EMU

In the years 2016 - 2017, the installation of an additional **100 - 150** systems for measurement of traction power consumption is planned in cooperation with rail operators in the Czech Republic.

A new type of EMU

- Compact design
- The electricity meter - Built-in control and transmission units DHS
- Using one connector Harting

Správa železniční dopravní cesty

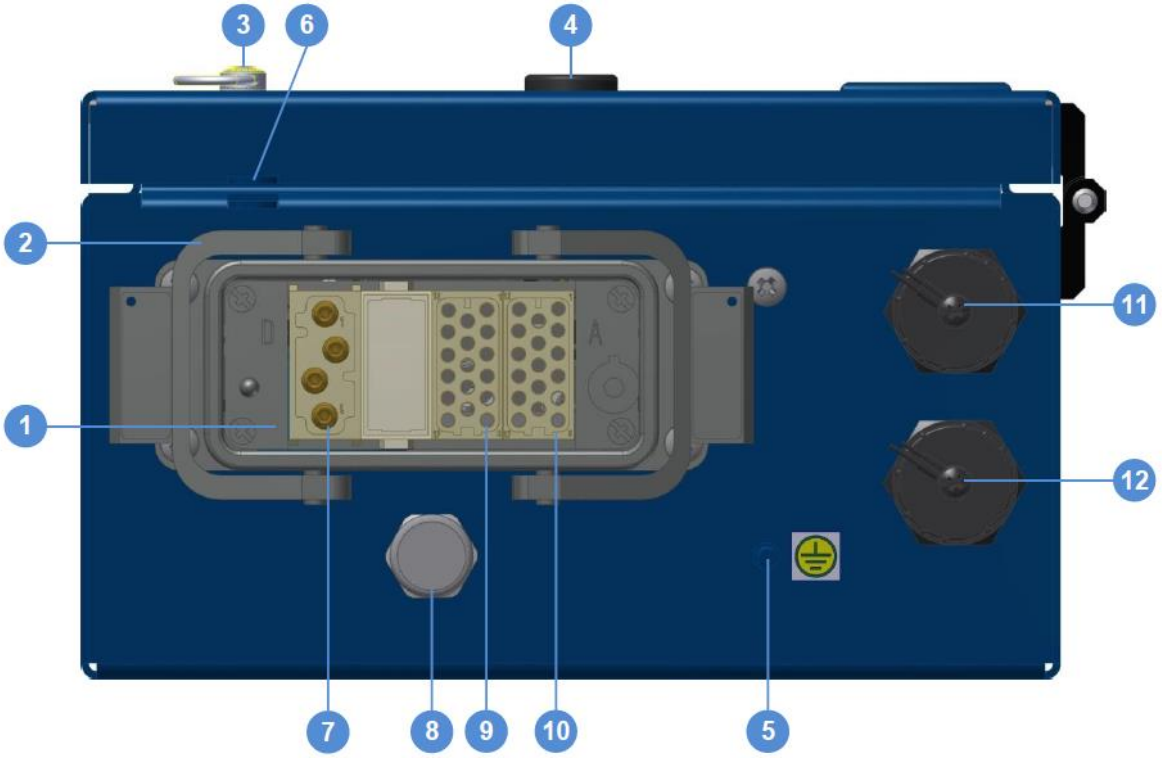
ELC-201 Front View

1 – ELM-201 Energy Meter
2 – Viewing Window
3 – Control Pushbutton
4 – Doors Quick Release

5 – K1 Connector
6 – K1 Connector Locking
7 – ETH Connector (RJ-45), IP65
8 – Backup Capacitor
9 – Hole for Doors Sealing

Správa železniční dopravní cesty

ELC-201 Bottom View



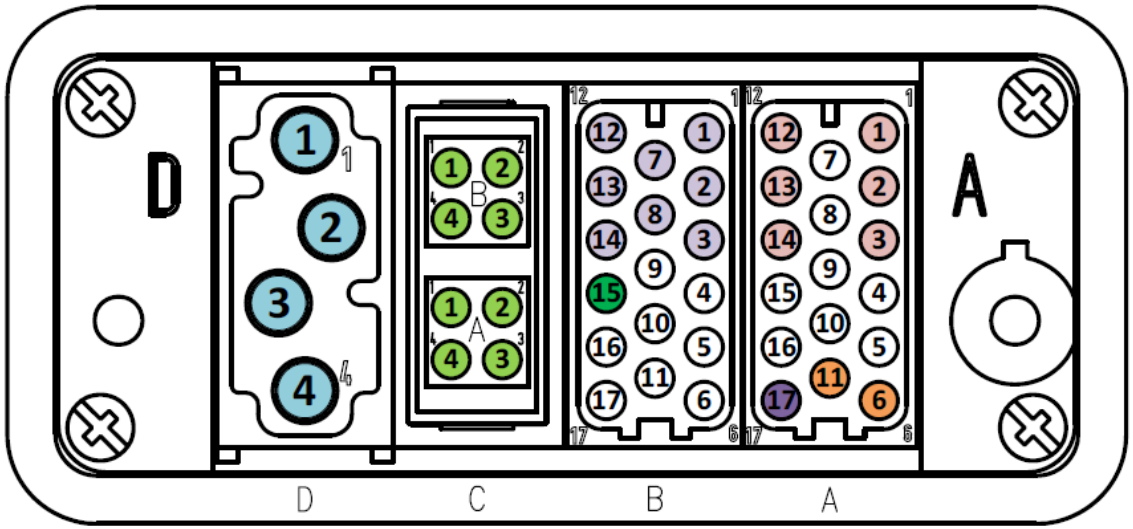
1 – K1 Connector
2 – K1 Connector Locking
3 – Doors Quick Release
4 – Control Pushbutton
5 – ELM-201 Grounding Point
6 – Hole for Doors Sealing
7 – GPS/GSM/GSM-R/Wi-Fi Antenna Connectors
8 – Pressure Compensator, IP66
9 – DC (IN2) Input / ±24V Output
10 – AC (IN1) Input / ELM-201 Power Input
11 – USB 1.1 Connector (USB-A), IP65
12 – ETH Connector (RJ-45), IP65

Správa železniční dopravní cesty

ELC-201 Connector Inputs / Outputs

AC and DC voltage and current inputs as well as all communication interfaces, antenna connectors and power supply input are available via a single K1 connector located on bottom side of the case. The K1 connector is composed of the following modules:

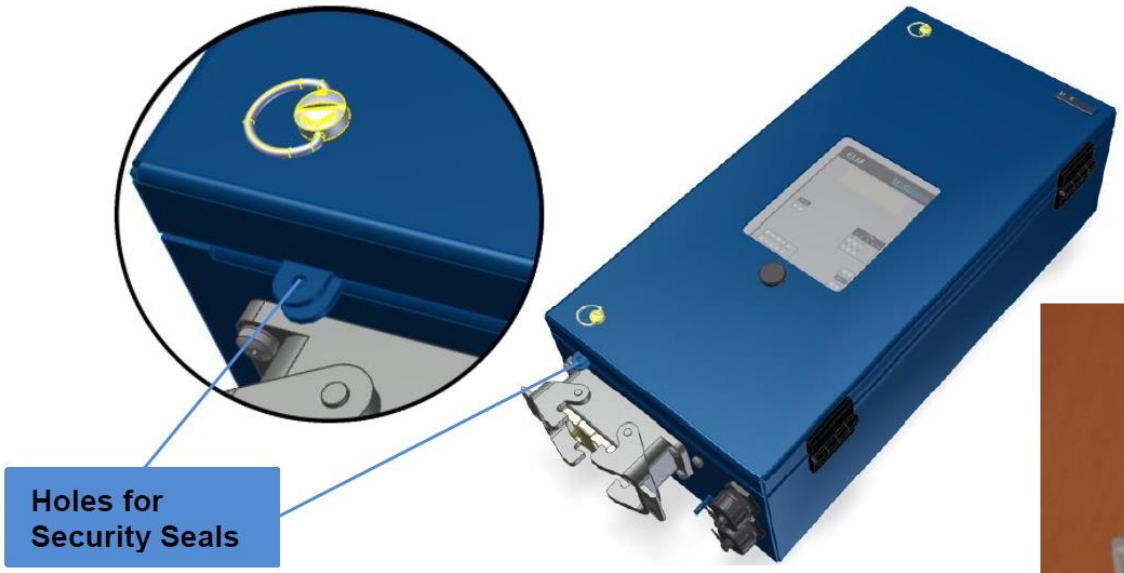
- a coaxial module for connection of antennas – see D position, Fig. 2-5
- a module for connection of Ethernet ports – see C position (unused for ELC-201/A)
- two 17-pins modules for connection of the ELM-201 power supply input, IN1/IN2 inputs and ±24V output – see A, B positions



Legend:

- Antennas Connectors (ANT-1 to ANT4)
- Ethernet (ETH-2, ETH-3)
- DC Input (IN2)
- AC Input (IN1)
- ELM-201 Power input (PWR)
- ELM-201 Grounding Point
- Test GND

ELC-201 Security sealing



Two holds with holes are available for sealing of the door and The connector quick release handles are provided for sealing the connector.

Správa železniční dopravní cesty

Current use of measured data at SZDC

- The measured data are not currently used for invoicing of traction consumption in the rail network.
- Data are analysed for the determination of specific consumption (kWh/grtkm) for different types of trains
- Some rail operators use the data to optimize the consumption of trains and assess individual trains.
- Especially **CD Cargo** (freight operator) is very active in this field.

Current use of measured data at SZDC

- Currently, discussions about the change of the system for invoicing traction consumption are being held with railway operators.
- The aim is to use measured data for invoicing traction consumption in combination with calculated data according to the recorded traffic for unmeasured trains.
- This system is scheduled to be implemented as of 1 January 2018, but without the introduction of open railway electricity market (TPA).

Správa železniční dopravní cesty

Outstanding problems at SZDC

- Implementation of standard protocol with the transfer of "delta values" of consumption?
  - SZDC prefers to use transfer of electrometer registers – „index value“
- Implementation and testing of electrometer according to MID (EN 50 470) or EN 50 463?
- Repeated testing of electricity meters in use
  - Period?
  - Only meters or include DC sensors?
- Introduction of accounting traction consumption by measured data – very important …

Správa železniční dopravní cesty

Thanks for your attention

www.szdc.cz