Vectron

Electrical Locomotive

Technical Description

Vectron MS

for operation in

Germany, Austria, Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Slovenia, Croatia, Serbia and Italy

The locomotive described herein is an already designed product.
Pictures may show optional components that are not included in the scope of delivery.

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1. Vehicle overview and summary

1.1 General information

The variant of the Vectron described in this document is a multi-system locomotive with 6.4 MW maximum power and a maximum speed of 160 km/h.

The locomotive is designed for operation in the following countries:

- Germany
- Austria
- Poland
- Czech Republic
- Slovakia
- Hungary
- Romania
- Bulgaria
- Slovenia
- Croatia
- Serbia
- Italy

1.2 Technical data

Voltage systems	AC 15 kV 16.7 Hz AC 25 kV 50 Hz DC 3 kV
Starting tractive effort (max.)	320 kN
Electrical braking effort (max.)	150 kN 240 kN (increased) [1]
Power at wheel rim (max.)	AC 15 kV 6,400 kW (Driving and regenerative brake) AC 25 kV 6,400 kW (Driving and regenerative brake) DC 3 kV 6,000 kW (Driving and regenerative brake) DC 3 kV 2,600 kW (Rheostatic brake)
Maximum speed	160 km/h
Ambient temperature	-30°C to +40°C (> Class T1, EN 50125-1:1999)
Max. altitude	1,400 m above sea level
Wheelset arrangement	Bo'Bo'
Track gauge	1,435 mm
Vehicle construction gauge	EN 15273-2+A1:2016 attachments A.3.2, A.3.3.2 and A.3.12
Vehicle length (length over buffer)	18,980 mm
Vehicle width (across handrails)	3,012 mm
Vehicle height (over driver's cab)	3,860 mm
Distance between bogie centres	9,500 mm
Wheelset distance in bogie	3,000 mm
Driving wheel diameter	1,250 mm / 1,160 mm (max. / min.)
Overall weight (max.)	90 t acc. to EN 15528:2015
Wheelset load (max.)	22.5 t acc. to EN 15528:2015
Smallest curve radius (line)	140 m
Smallest curve radius (depot) (without removing components)	80 m (at v≤5 km/h, not coupled single locomotive)
Smallest convex transition radius	250 m
Smallest concave transition radius	300 m

[1] If permitted and homologated in the corresponding country, the locomotive driver can select the increased electrical braking effort characteristic on the display.

1.3 Tractive / braking effort diagram

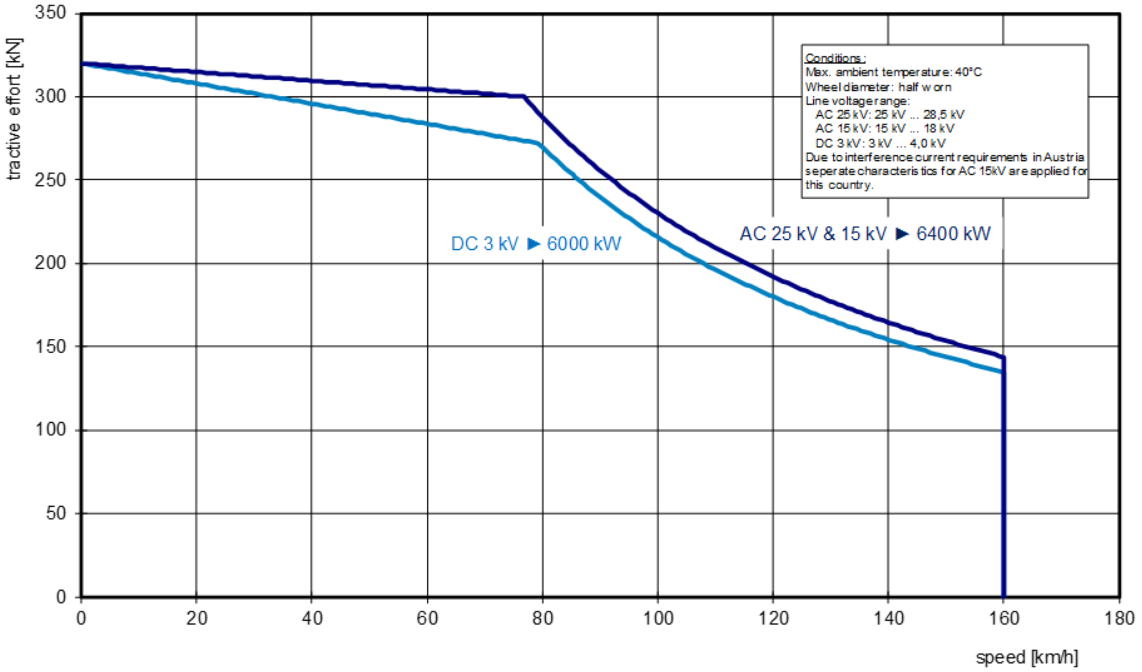

Figure: Maximum tractive effort at wheel rim

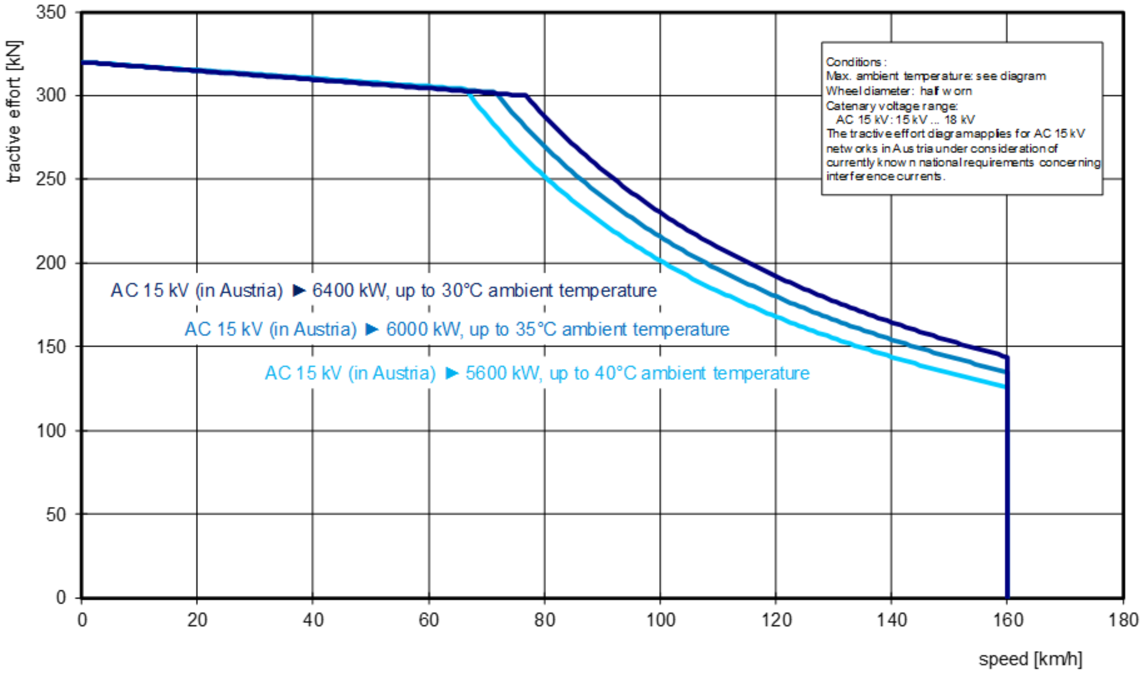

Figure: Maximum tractive effort at wheel rim for Austria

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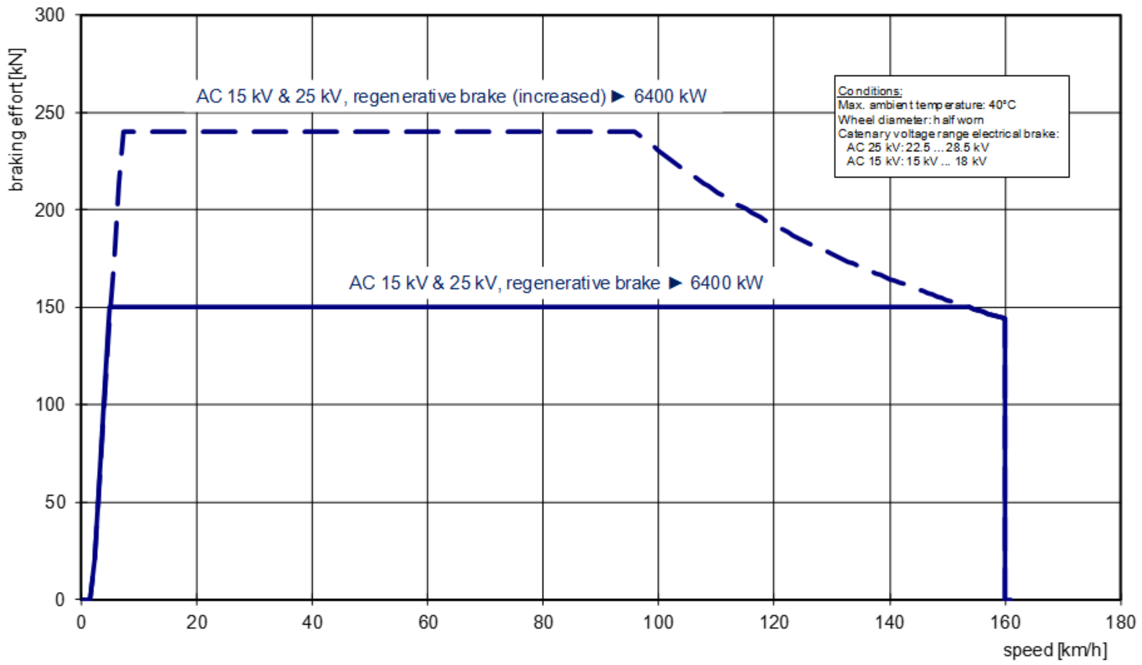


Figure: Maximum electrical braking effort at wheel rim (AC-mode)

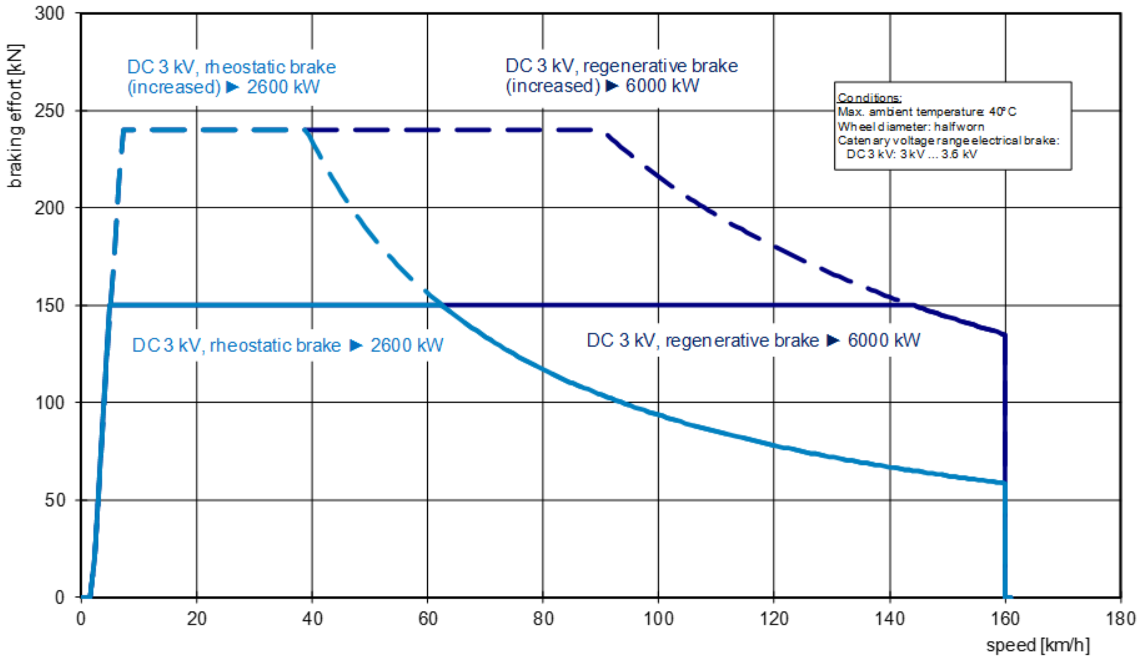


Figure: Maximum electrical braking effort at wheel rim (DC 3 kV-mode)

The electrical braking effort may be affected by additional country specific limitations, which are not described in these figures.

If permitted, the locomotive driver can select the increased electrical braking effort characteristic on the display.

The tractive and braking characteristic curves require an adequate adhesion value between wheel and rail. The maximum utilization of the available adhesion value is enabled by a highly effective electronic slip/slide control.

1.4 Mechanical design

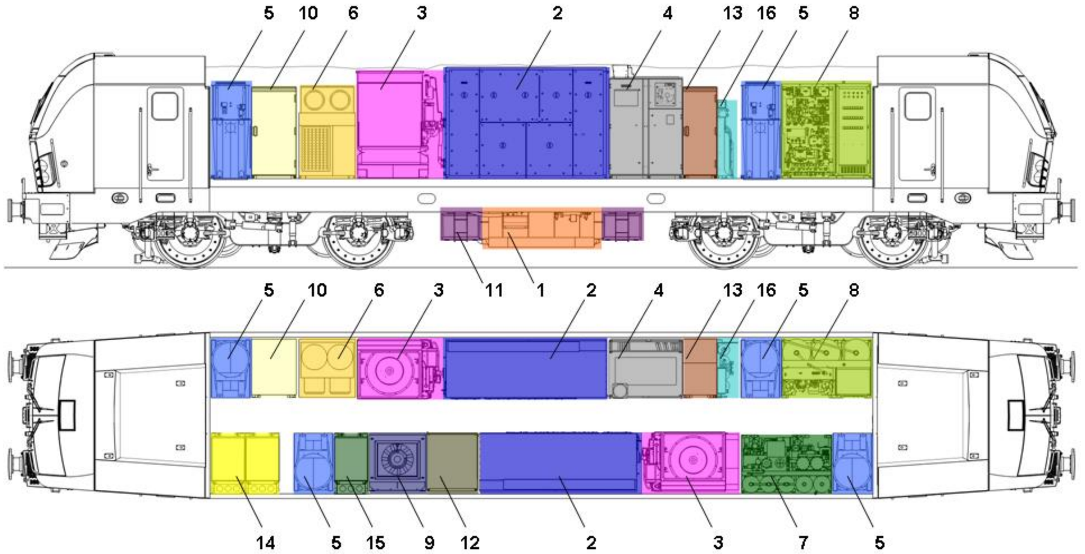
The mechanical design is based on a modular arrangement with predefined mounting spaces and offers high flexibility and modularity. This modularity is implemented in all important areas: the main electrical components, the train protection systems cubicles, the antenna and sensor configuration underfloor, the roof antennas and the driver's desk configuration.

This comprehensive, flexible and fully modular concept permits simple conversions or retrofitting of predefined country and option packages to ensure quick adaptation of the locomotive to changing corridors and areas of operation.

The locomotive has an integral body with two driver's cabs at the ends. The centre gangway enables in case of emergency an intuitive escape by a straight and clearly arranged emergency exit through the machine room. Due to the high strength requirements, the locomotive body is designed as a self-supporting lightweight steel structure which is divided into the main components of underframe, driver's cabs including driver's cab rear walls and machine room side walls.

Each driver's cab is separated from the machine room by a steel rear wall which can be entered through a door in the middle from both driver’s cabs.

The roof consists of three removable segments which also support the roof equipment. Via these roof openings devices in the machine room are easily accessible.



1 main transformer	9 brake resistor
2 traction converter	10 low-voltage rack
3 oil and water cooling tower	11 battery box
4 DC high-voltage rack	12 AC high-voltage rack
5 traction motor fan	13 auxiliary rack
6 auxiliary transformer rack	14 train control cabinet 1/2
7 compressed air generation unit	15 train control cabinet 3
8 brake control rack	16 fire-fighting system

Figure: Machine room layout (side view and top view)

The locomotive fulfils crash scenarios 1 to 4 in accordance with DIN EN 15227:2011 with all the requirements for the survival area for the driver, the maximum deceleration limits in the locomotive body and the requirements to reduce the risk of overriding.

1.5 Traction and auxiliary concept

The traction system of the locomotive consists of two traction converters with IGBT power semiconductors and four three-phase asynchronous traction motors. Each traction converter is assigned to one bogie and powers two traction motors.

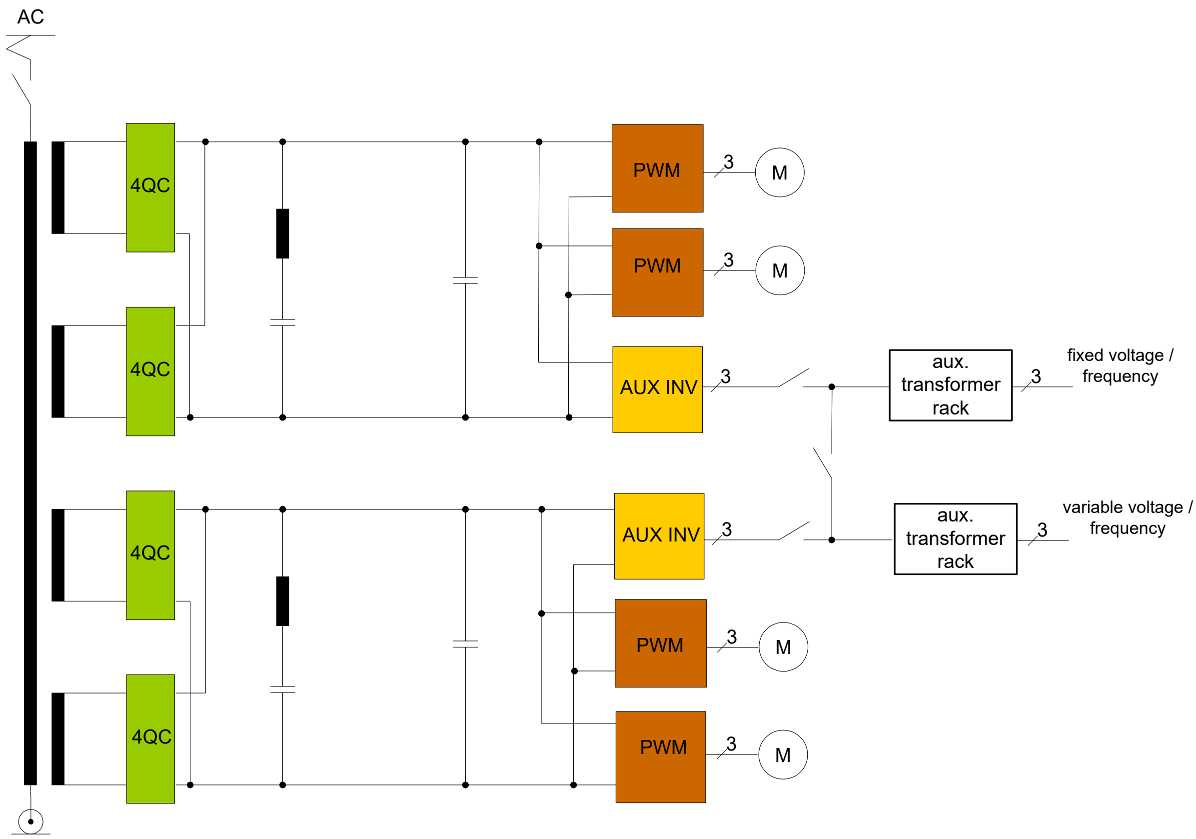


Figure: Simplified circuit diagram in AC mode

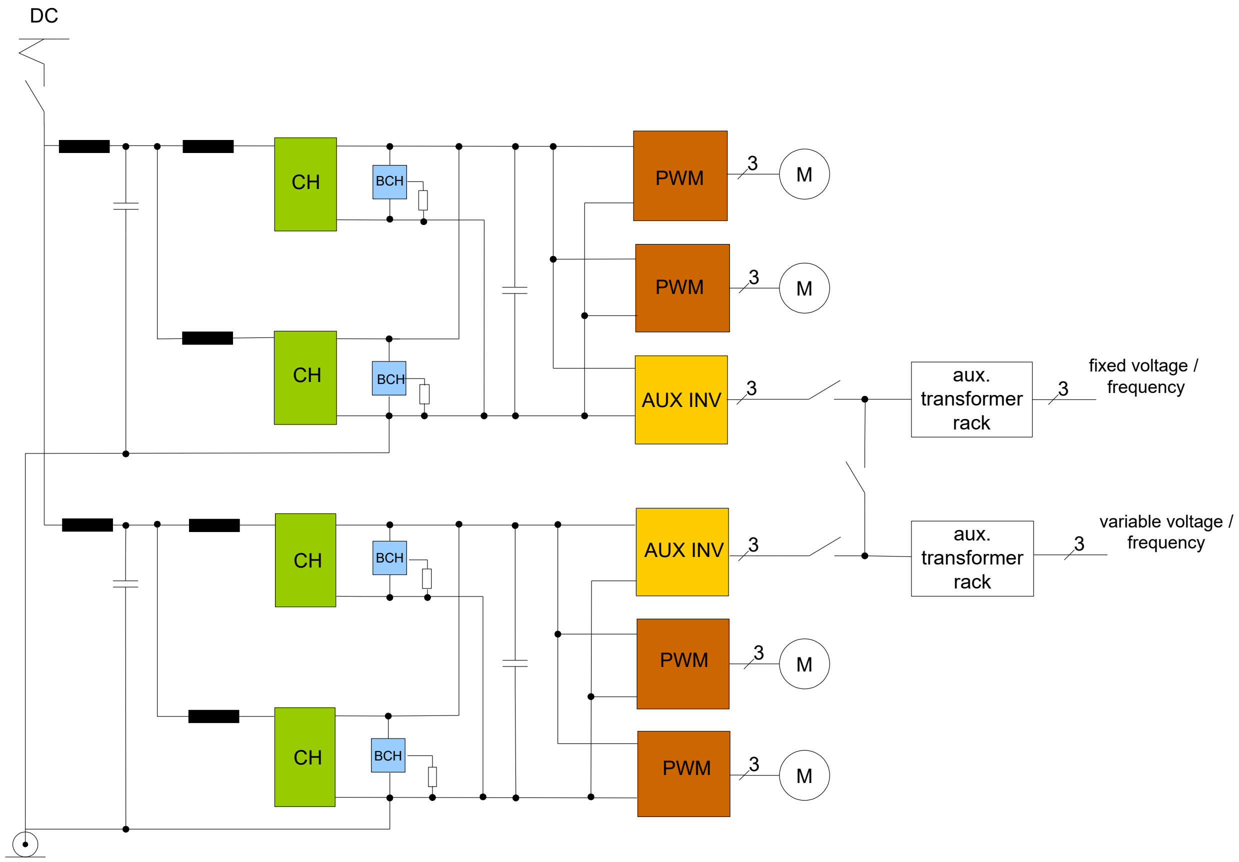


Figure: Simplified circuit diagram in DC mode

Each traction motor (M) is supplied with variable voltage and frequency by a pulse width modulation inverter (PWM) from the voltage DC link.

The single axle control enables an optimum of traction force utilization.

In AC mode, each DC link is supplied by two four-quadrant choppers (4QC) each working on separate transformer secondary windings.

In DC mode, the DC links are supplied by a line filter and two step-up choppers (CH) from the catenary system.

Depending on the line capacity, in brake mode the power generated by the traction motors is fed back into the catenary system (regenerative braking).

Additionally, the brake chopper (BCH) and brake resistor can be used for electrical (rheostatic) braking in DC mode.

The circuit design of the locomotive allows the cut-out of one of the two bogies in the event of a fault.

Both traction converters are equipped with an auxiliary inverter (AUX INV) each. These feed two 3AC 440 V 60 Hz auxiliary circuits (with variable and fixed frequency) to supply the auxiliary consumers within the locomotive.

2. Locomotive body

2.1 Locomotive body shell

2.1.1 Overview

The locomotive body shell consists of the underframe, two driver's cabs, the side walls and two cross-sectional stiffeners. It is self-supporting, made entirely from steel and fully welded apart from the two screwed cross-sectional stiffeners. The welding is carried out using laser-hybrid-technology. The front section of the driver's cab is a replaceable crash end.

2.1.2 Repair after a collision

When developing the locomotive special attention was paid to a simple and low cost repair option after a collision. In case of smaller collisions, bolt-on deformation elements outside the vehicle structure can be exchanged easily.

One of the special features of the Siemens vehicle design is that the deformation zone within the vehicle, known as the crash end, is connected to the locomotive body using removable connections.

Thus, a simple repair is possible without having to replace major structural components using an angle grinder, cutting torch and welder. This significantly reduces the down times of the locomotive in case of repair.

In case of crash scenarios according to DIN EN 15227:2011 deformations of the welded locomotive body do not occur.

2.2 Draw and buffing-gear

The following draw and buffing-gear are attached to each end of the locomotive:

- 1500 kN coupling system in accordance with DIN EN 15566:2011, consisting of:
  - draw gear in accordance with DIN EN 15566:2011 with Siemens flange and train hook with a breaking load of 1500 kN.
  - a screw coupling in accordance with DIN EN 15566:2011 with a breaking load of 1350 kN; the screw coupling exceeds the requirements set out in UIC 520:2003 and UIC 826:2004.
  - a tension spring system with elastomer spring in accordance with UIC 827-1:1990.
- two side buffers (central flange buffers) in category C (70 kJ/buffer) in accordance with EN 15551:2009 and UIC 527-1:2005 with elastomer spring in accordance with UIC 827-1:1990, hydraulic element and energy absorption element connected behind. The side buffers also fulfill the requirements of UIC 526-1:2008, which do not contradict those in EN 15551:2009.

The tractive and braking efforts of double heading (tension: 600 kN, compression: 300 kN) can be permanently absorbed through the draw and buffing-gear in the underframe.

2.3 Paint

The paint chosen for the different areas and components considers the function as well as the location and the appearing stresses. The paints are free of lead and zinc chromate. The coating is in accordance with the requirements of the Federal Immission Protection Act dated 31/10/2007. In order to meet these requirements, the paints used are almost exclusively water-soluble. Non-rusting parts of racks and the underside of the roof (aluminium) are not painted.

The paintings of the locomotive are widely standardized. The underfloor area, front section and roof are painted consistently in RAL 7022 (colour: umber grey). Dirt is less visible on this colour shade. The colours for the internal areas are also standardized.

The customer can choose two colours for the design area outside of the locomotive body (above the side longitudinal supports).

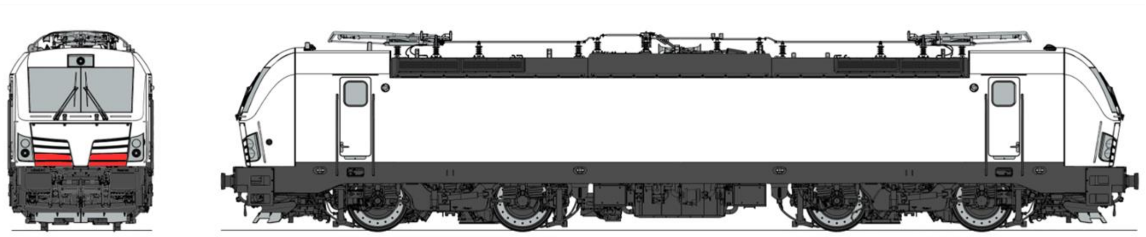


Figure: Design area

White area:	Design area, two-coloured, colours can be chosen by the customer
Dark grey areas:	RAL 7022 umber grey
Red areas:	RAL 3020 (traffic red) acc. to Italian homologation requirements
Light grey areas:	Glass or steel areas

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2.4 External lighting and signalling

2.4.1 Front and rear signals

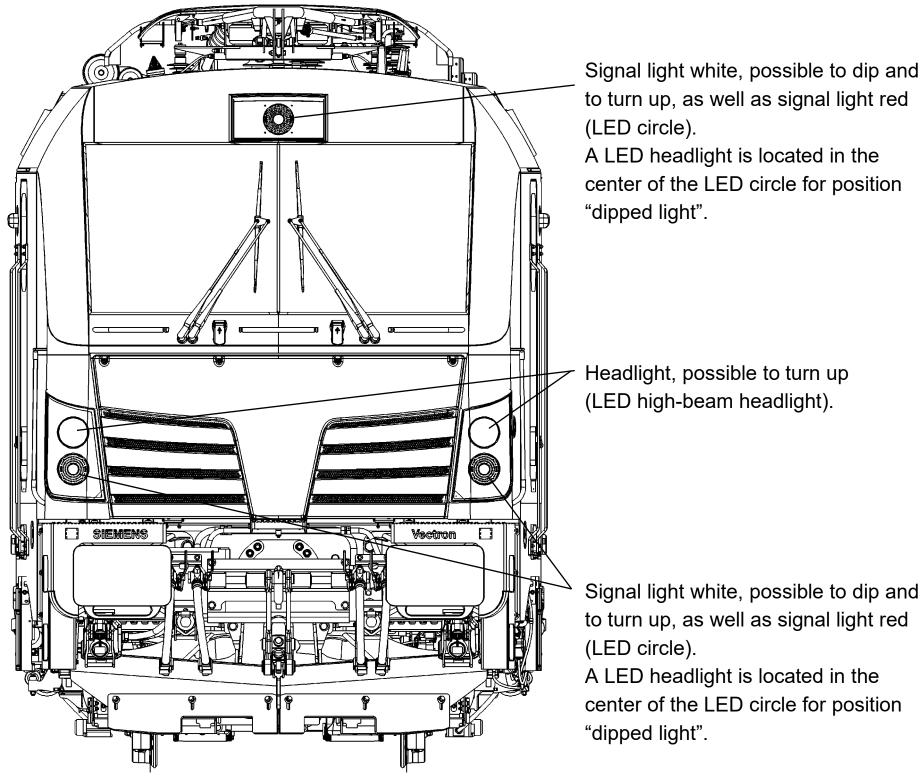

Figure: Configuration of signal light and headlight

2.4.2 Operation

The signal aspect is configured from the display.

The light intensities "signal light", "signal light dipped", "off", "dipped light" and "high beam light" can be selected using a switch on the driver's desk.

2.4.3 Acoustic signals

There are two train horns fitted for each direction of travel (370 Hz or 660 Hz). The actuation of the high and low tone is done manually either individually with a lever on the driver's desk or from the side control unit or combined via foot switch located in the foot niche.

3. Underfloor arrangement

3.1 Main transformer

The main transformer is suspended on four points below the locomotive body on the transformer cross struts between the bogies.
The transformer cooling circuit is connected to the two cooling systems inside the machine room using flexible hoses and compensators.

3.2 Battery box

The two battery containers are aluminium constructions which are attached to the underframe on one side of the locomotive on the right and left side of the transformer tank. They are self ventilating and extracting.

3.3 Antennas for train control

Depending on the system used, the antennas required for the built-in train control systems are fitted at the bogies or on special consoles at the locomotive body.

Additional mounting places are kept in reserve for further train protection antennas, which allow the operator to extend the operation area of the locomotive. The mounting locations and fastenings of the antennas are standardized to simplify upgrading.

3.4 Sanding

The sand distributor consists of eight individual sanders. Each sander is assigned to a locomotive wheel. The sand is ejected in front of the wheels of the relevant front axle of both bogies, depending on the direction of travel.

There is a heating of the sand box and the sand pipe which, together with the drying air, ensures that the sand does not get clogged up.

Each sand box contains up to 60 l of sand and has a ventilated folding lid. The sand boxes can be filled by hand or using suitable sand filling equipment.

3.5 Wheel flange lubrication

Depending on the direction of travel, the wheel flanges of the respective front wheelset in each bogie of the locomotive are lubricated (axles 1+3 or 4+2).

The necessary consumables like sand, lubrication materials and window cleaning water can be filled up time saving from outside without polluting the machine room or the driver's cab.

4. Driver's cab

4.1 Overview

Both almost identical driver's cabs at the ends of the locomotive are based upon the requirements of UIC 651:2002. The driver's cab is accessible through two outside doors and a fire protective machine room door (with emergency opener on the driver's cab side).

Each driver's cab has two full-fledged seats, one for the locomotive driver and one for a co-driver, with the driver sitting on the right.

A thermo box is arranged at each driver's cab rear wall for cooling or heating of food and beverage.

4.2 Entrance doors

The two entrance doors on the right and left each have a clear width x height = 650 mm x 1675 mm. These doors open approx. 80° inwards and swing open towards the rear wall of the driver's cab. There is a lowerable side window in each door.

The door on the right side in the direction of travel is fitted with a door handle and a lock (DB Kreuzbart locking system) on the lower right-hand side. On the inside of the door, the door handle is designed as a turning lever and is located on the left halfway up the door, seen from the inside.

The door seal is pressed on by pulling up this turning lever beyond the horizontal position. In addition, the door has a fixed handle in the lower left area on the outside to allow it to be closed when reaching out from track level.

The door on the left side in the direction of travel is mirror inverted.

4.3 Front windscreens

The front windscreens have two sections and are glued into the vehicle from the outside. They are made of laminated safety glass. The screens are electrically heatable. There are blinds on the front windows.

4.4 Windscreen wipers

The locomotive has two electric windscreen wipers for each driver's cab, which clear a visible area at least in accordance with UIC 651:2002 and DIN 5566-2:2006. Via a switch at the driver's desk an interval operation and two continuous wiping speeds can be chosen. For cleaning of the windscreens a splash water system is installed with a capacity of approx. 28 l. It can be filled from the outside of the vehicle.

4.5 Rear view facility

There are two video cameras fitted to the outside of each driver's cab (left/right) as a rear view facility. The camera picture is shown on a display.

4.6 Seats

The driver's seat is air sprung, pneumatically height-adjustable and has a damper adjustment. The upper part of the seat can be adjusted longitudinally with a snap-in mechanism. The backrest has a pneumatic side- and lumbar-support. The seat cushion is adjustable in depth and inclination. For driving in a standing position and for a quicker emergency leave, the seat can also be shifted completely to the rear. The driver's seat has a height-adjustable and inclinable headrest and two armrests that can be folded up and adjusted in inclination. These features offer the driver the best possible comfort.

The co-driver’s seat has a gas pressure spring for mechanical height adjustment. The backrest has cushioned-formed side- and lumbar-support. Apart from this, it is constructed similar to the driver's seat.

4.7 Ergonomics, operation

The modular designed driver's desk with standardized mounting positions was ergonomically designed based on the directive UIC 612-0:2009 with further optimizations.

Great importance was attached to good accessibility, visibility and non glaring for all elements.

The rear wall cabinet contains a control panel according to UIC 612-0:2009 where additional less frequently required controls are located, although the number and design of individual controls may differ.

4.8 Controls and displays

4.8.1 Driver's desk

Figure: Driver's desk (example)

4.8.2 Side control unit

The side control unit is located at the side wall next to each entrance door. It allows starting the train while looking out of the side window. Operation elements for horn, door control, train protection, driving direction, tractive effort and direct brake for example are part of the side control unit.

4.9 Driver's cab lighting

The main lighting of the driver's cab is provided from the ceiling by two lights. The driver's desk is illuminated with at least 75 Lux according to EN 13272:2012.

Both lights can be activated via switches at the entrance doors. The switches are located in the floor area inside the driver's cab, so they can be easily reached from the outside. Another switch is located on the driver's desk. The lighting switches off automatically with a time delay of 15 minutes if the vehicle battery is not being charged. The lighting can be switched on again immediately.

4.10 Air-conditioning

Both driver's cabs are air conditioned and are pressure protected by low noise pressure protection fans. Each driver's cab is equipped with one air-conditioning system for filtered mixed and fresh air.

The floor, the ceiling and the walls are protected with continuous heat insulation. The driver's cab is insulated effectively against noise, draughts and temperature effects from the machine room.

The filtering of the fresh air with a cyclone separator and a filter cartridge protects the locomotive driver effectively from dust, pollen and grime.

Each driver's cab is equipped with an electrical floor heating.

5. Bogie

5.1 General information

The bogie is characterized by following features:

- Robust, fully welded bogie frame
- Reduced longitudinal stiffness of axlebox linkage to provide good curve running behaviour
- Tractive force transfer by means of low level traction linkage with a pivot to the central support beam of the bogie frame
- Secondary spring (flexicoil suspension)
- Hollow pinion shaft drive for low unsprung mass
- Wheel disk brakes
- Prepared for the mounting of train control antennas for different European countries
- Good accessibility to the areas to be checked during the maintenance periods is provided by the design. Wear and tear components are also easily accessible

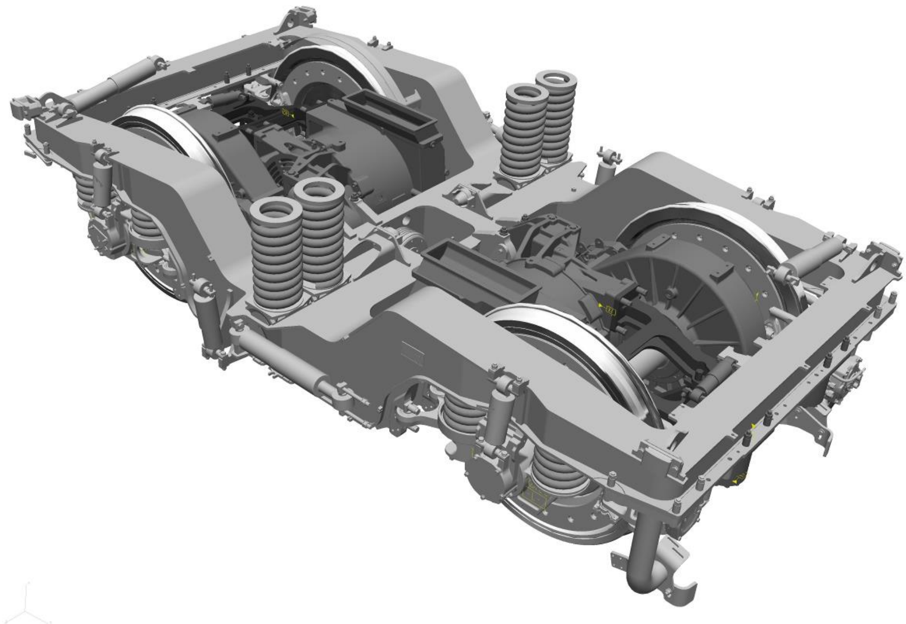

Figure: Principle of the bogie

5.2 Running characteristics on the rail track

The derailment safety complies with EN 14363:2005.

The locomotive achieves the comfort category "medium" to "comfortable" according to the definition of EN 12299:2009 on rail tracks according to EN 14363:2005 / UIC 518:2009. This applies to the combination of wheel and track profiles S1002 according to DIN EN 13715:2011 on UIC rail track profiles with inclination from 1:20 to 1:40.

5.3 Track levels supported

The locomotive is designed to run on track levels as defined in EN 14363:2005 / UIC 518:2009 QN2. The minimum track curve radius to be passed during commercial operation is 140 m. The minimum track curve radius for the depot is 80 m at walking pace ($v \leq 5$ km/h; uncoupled single vehicle).

According to EN 15273-2:2013+A1:2016 the smallest concave transition radius is 300 m and the smallest convex transition radius is 250 m.

6. Energy supply

6.1 Pantograph

The locomotive is equipped with the following arrangement of pantographs:

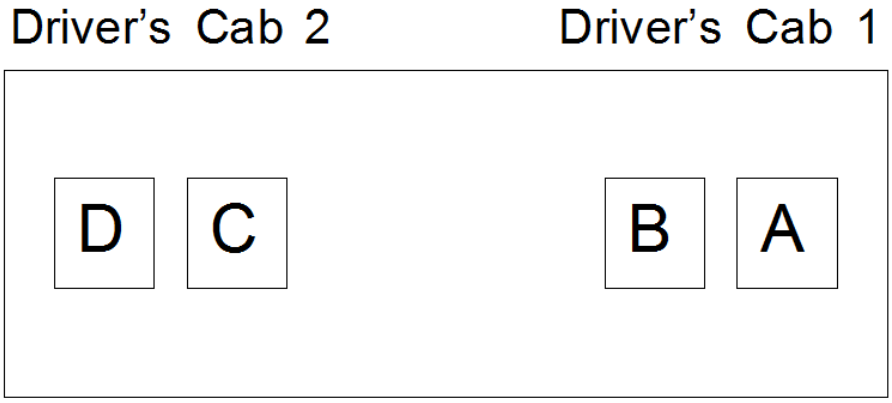

Figure: Pantograph arrangement

In position A, there is an AC pantograph with collector head length of 1600 mm and two carbon contact strips (700 A) for the 25 kV networks in Croatia and Serbia.

In position B, there is a DC pantograph with collector head length of 1450 mm and two metalized carbon contact strips (2560 A) for the 3 kV networks in Slovenia and Italy.

In position C, there is a DC pantograph with collector head length of 1950 mm and two metalized carbon contact strips (2560 A) for the 3 kV networks in the Czech Republic, Poland and Slovakia.

In position D, there is an AC pantograph with collector head length of 1950 mm and two carbon contact strips (700 A) for the 15 kV networks in Germany and Austria as well as for the 25 kV networks in Hungary, Czech Republic, Slovakia, Romania and Bulgaria.

All pantographs are provided with an automatic high-speed lowering, which lowers the pantograph quickly if the contact strip breaks.

6.2 Energy meter

The locomotive is prepared for the installation of an energy meter in accordance with EN 50463:2017. The corresponding current and voltage transducers are installed.

7. Traction equipment

7.1 Main transformer

The main transformer is designed as AC 15 kV 16.7 Hz and AC 25 kV 50 Hz single phase transformer.

In DC mode, the secondary windings are used as line filter reactors.

7.2 Traction converter

7.2.1 Traction converter design

Each of the two traction converters is located in a separate cabinet. Each bogie is assigned to one traction converter.

Each traction converter is equipped with its own traction control.

The traction converter cabinets are IP54 encased (dust and splash-proof). The entire cabinets can be removed and fitted through the roof opening if the central roof panel is removed.

The power electronics of the traction converter is based on IGBT technology (insulated gate bipolar transistor) with the following characteristics:

- Compact design due to water-cooling.
- Low-maintenance arrangement of IGBT in modular form.
- The higher pulse frequency of IGBT technology compared to GTO (gate-turn-off thyristor) technology, results in a lower harmonic content in the overhead line system in AC voltage operation.

The electro-dynamic brake works as a regenerative brake if the overhead contact line is receptive to the feedback of braking energy.

There is also a rheostatic brake for operation in direct current networks.

7.2.2 Input chopper and DC link

In each traction converter there are two input choppers (CH) which work as four quadrant choppers (4QC) in AC mode. These 4QC, each working on separate transformer secondary windings, feed the connected DC links and the 33.3 Hz or 100 Hz resonant circuit connected in parallel.

In DC mode, the connected DC link circuits are supplied by a two-stage line filter and two step-up choppers (each consisting of one phase of each 4QC, which is not used in DC-operation) from the line power. The transformer secondary winding and the resonant circuit capacitor form the line filter. The resonant circuit reactors serve as chopper reactors.

7.2.3 Traction inverter

There are two traction inverters (PWM) within each traction converter. The PWM allow an energy flow in both directions (traction/braking).

Each traction motor (M) is connected to a separate PWM. The PWM supplies the traction motor with variable voltage and frequency.

7.2.4 Brake chopper

In DC mode, the 4QC phases (AC mode) which are not used as step-up choppers serve as brake choppers. Thus every traction converter disposes of two separate brake choppers (BCH).

7.2.5 Auxiliary inverter

Each traction converter contains an auxiliary inverter (AUX INV) to supply the auxiliary systems within the locomotive. It is connected to the DC link. The output voltage of the AUX INV is then filtered and isolated using a three-phase transformer and filtering capacitors.

7.3 Drive

7.3.1 Overview

The locomotive is equipped with four semi-suspended hollow pinion shaft drives. This drive solution features a small non suspended mass and thus enables a track conserving operation with low wheel – track contact forces.

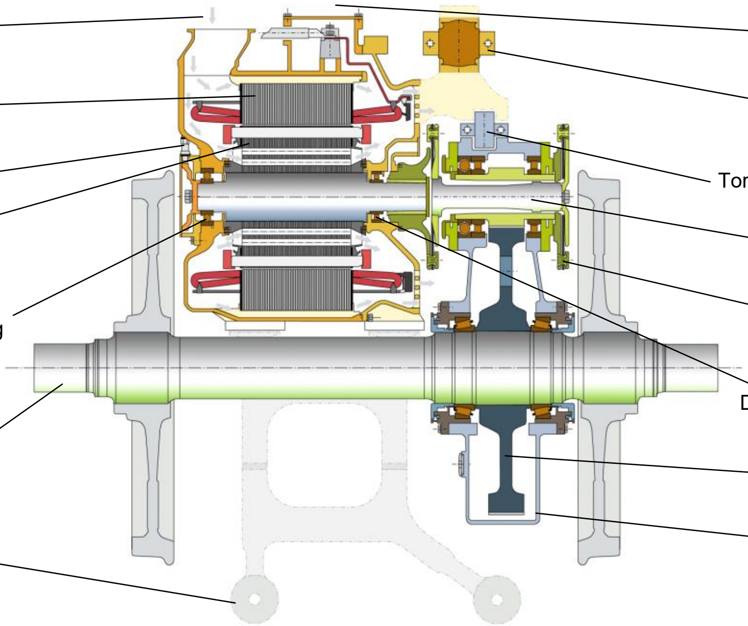

Figure: Semi-suspension hollow pinion shaft drive with steel lamination coupling (principle diagram)

7.3.2 Traction motor

The three-phase current asynchronous motor with squirrel-cage rotor fitted in parallel to the wheelset shaft is designed for use on traction converters without motor input chokes. It is externally ventilated by a traction motor fan fitted in the machine room.

7.3.3 Gears

The gear unit is located on the wheel set shaft and is supported by a torque arm at the motor.

8. Cooling of traction equipment

The locomotive is equipped with two cooling towers. Each cooling tower cools one traction converter and one half of the main transformer. Therefore two cooling disks lie on top of each other, which are cooled by a common air flow. The air is taken in through the roof and blown out underfloor.

The two cooling tower fans as well as the four traction motor blowers are connected to the variable-frequency three-phase on-board power supply.

9. Vehicle control and communication

9.1 Structure of vehicle control

Major vehicle control components are: [2]

- Central control units (CCU)
- Main control units (MCU)
- Traction control units (TCU)
- LCD colour displays (CCD, TDD) on the driver's desks
- Brake control unit (BCU)
- Wheel-slide protection (WSP) for the pneumatic brake
- Peripheral connections through distributed input-/output modules (I/O)
- Vehicle bus gateways for multiple unit traction control
- Automatic train protection (ATP) systems
- Data recorder
- Remote data transmission unit (RDA)

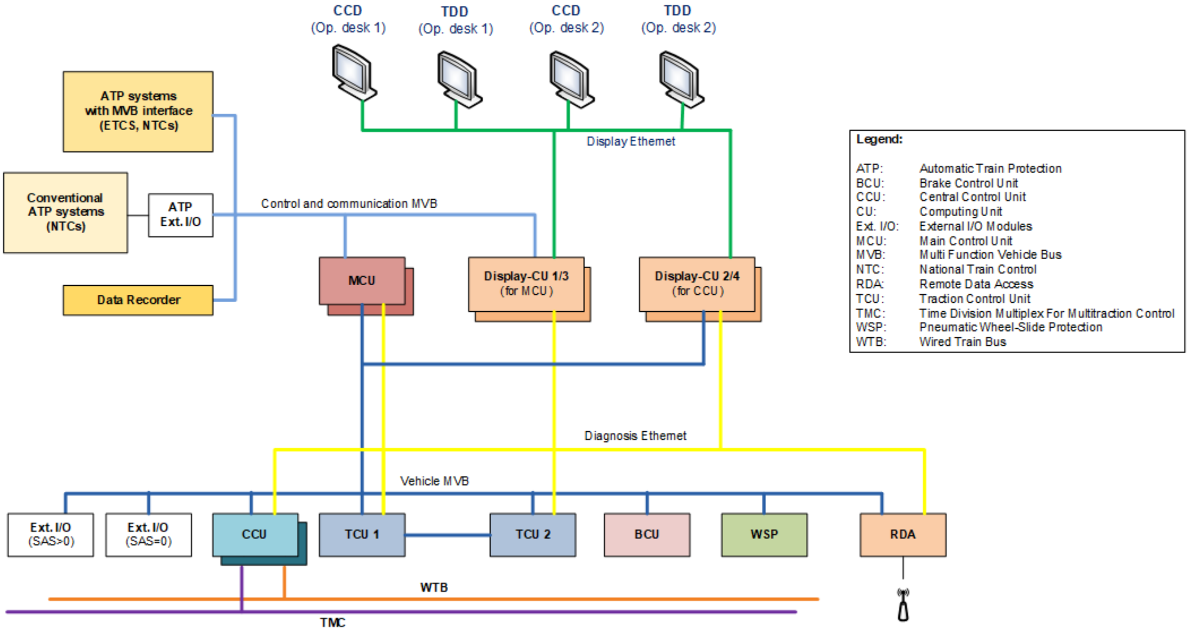

Figure: Vehicle control architecture

For service purposes the central control units, the traction control units, the main control units and the display-control units are connected to each other via a separate Ethernet based service bus. This service bus is easily accessible to service personnel via an Ethernet interface in each driver's cab and offers the option of remote diagnostic data transmission via the digital radio interface (RDA).

[2] Technical changes reserved.

9.1.1 Displays

The LCD colour displays CCD and TDD are integrated in each driver's desk.

The CCD (Control and Command Display) located in the central driver's desk console provides essential information for controlling the locomotive, e.g. vehicle speed, tractive and braking effort and information of train control systems.

The TDD (Technical and Diagnostic Display) located in the right driver's desk console is used for visualizing vehicle conditions and diagnostic information as well as for the input of several operator control actions.

If one display fails, it is possible to operate the locomotive with only a single functioning display in "one-display mode".

9.1.2 Data recording

Data is recorded on a data recorder which fulfils the national and network specific approval criteria in the relevant countries. The memory can be read out via separate application software.

9.1.3 Remote data access (RDA)

The locomotive is equipped with a remote data access system for transmission of diagnostic and GPS position data. Sufficient network coverage is required for landside transmission.

Note: Landside data access has to be agreed separately.

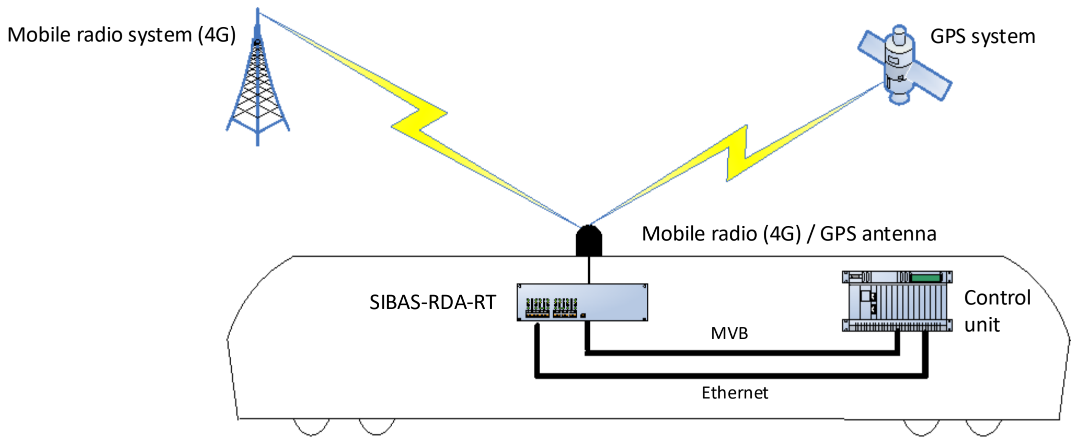

Figure: Principle sketch of data remote transmission

9.2 Important functions of the central control unit

9.2.1 Automatic speed control (ASC)

The automatic speed control (ASC) is implemented as software feature in the vehicle control and is designed as comfortable cruise control to support the driver.

The ASC maintains the train speed within tight limits of the speed guidelines set out by the vehicle driver or the train control system (LZB, ETCS). The vehicle is always moved in compliance with the comfort conditions based on acceleration and deceleration limits. This applies to speeding up, slowing down or braking to the required speed. The ASC can use the indirect brake when the BP controller is in electronic mode as well as in backup mode.

9.2.2 Slip control

The locomotive is fitted with a highly efficient slip control, which allows a maximum utilization of the present adhesion coefficient between wheel and rail.

The tractive force control prevents the wheelsets from slipping accidentally (slip protection). However, controlled slip within allowed limits has a positive effect on the drive's utilization of tractive force. If the driver demands a maximum utilization of the tractive power between the wheel and the rail by setting a high tractive force set value, the drive begins moving the wheelsets faster compared to the vehicle speed in order to roughen up the running surfaces of the wheels (which improves the utilization of tractive power).

9.2.3 Remote control of coupled locomotives (multiple unit traction)

Non leading (unoccupied) locomotives can be remote controlled from a leading locomotive (occupied with driver). For this the vehicle control software of the leading locomotive generates control commands for the guided locomotives and sends them to the guided locomotives via the train bus WTB (WTB ÖBB) or via TMC (ZDS/ZMS).

Note: There could be restrictions due to country specific approvals for multiple unit operation.

9.2.4 Energy saving functions

9.2.4.1 Eco-Mode

The locomotive provides an eco-mode, which can be manually activated by the driver when the locomotive is parked ready for operation.
In eco-mode certain subsystems of the parked locomotive are deactivated. Vehicle control, electrical power supply from the overhead line and manually activated comfort functions as e.g. light, heating/air conditioning and thermo box keep switched-on. When the eco-mode is activated the train line supply will automatically return to the previous switching status.

If the main circuit breaker opens during the eco-mode in case of a line voltage incident, the main circuit breaker will reclose automatically when the regular line voltage returns.

9.2.4.2 Indication of energy consumption

As a motivation for the driver for an economical driving the absorbed and recovered energy is shown for information on the display.

9.3 Vehicle diagnostics

The diagnostics system provides the locomotive driver and the workshop personnel with comprehensive information about the status of the locomotive and allows the vehicle owner to analyse the technical condition of its vehicle fleet.

For the driver of the locomotive the vehicle diagnostics is shown on the Technical and Diagnostics Display (TDD).

The diagnostics data for workshop personnel can be downloaded for further analysis via service interfaces located in the driver's cabs using a mobile computer and adequate service software.

9.4 Train radio

The train radio equipment of the locomotive consists of the following systems:

- GSM-R
- 450 MHz analogue radio
- 160 MHz train radio for Poland, Hungary, Czech Republic, Slovakia and Romania

Even when the locomotive is shut down the train radio can be activated by a separate push button for a duration of 30 minutes.

10. Pneumatic system and brake

10.1 Air generation and treatment unit

All devices which form part of the compressed air supply and preparation system are integrated into a compressed air generation unit.

The compressed air volume flow required to supply compressed air to the locomotive and the train is generated using an electrically powered compressor.

The compressor has a delivery rate of approx. 2400 l/min of free air at operational pressure.

It is an oil-free piston compressor.

The maximum duty cycle of the compressor is 100 %.

Due to the fact that the compressor is integrated in the machine room it is optimally protected and easily accessible for maintenance.

10.2 Compressed air storage and distribution

The locomotive has a main air reservoir of 975 l for storage and buffering the compressed air generated by the compressor.

10.3 Auxiliary air system

The auxiliary air system supplies the pneumatically operated high voltage components with compressed air.

When the system is operational, i.e. the main reservoir pressure is available, the auxiliary air system is supplied by the main air system.

An electrically battery powered, oil-free compressor is used as an auxiliary compressor.

10.4 Controlling the automatic train brake (brake pipe pressure control)

10.4.1 Driver's brake valve

To control the pressure of the brake pipe (BP), there is a position-dependent, electronically controlled driver’s brake valve with a backup controller.

The driver's brake valve is in accordance with UIC 541-03:1984. It consists of the control lever in the driver's desk, an electronic brake control unit and associated electro-pneumatic and pneumatic components.

10.4.2 Indicators

The current brake pipe (BP) pressure, the current main reservoir (MR) pressure as well as the bogie related brake cylinder pressures C1 and C2 are shown on the display at the driver's desk.

10.5 ep-brake and emergency brake override (EBO) / passenger alarm signal (PAS)

The following modes of the ep-brake and the emergency brake override are provided:

- ep-brake based on UIC 541-5:2005
- emergency brake override (EBO) acc. UIC 541-5:2005
- simplified ep-brake acc. UIC 541-5:2005
- ep-brake based on DB system
- emergency brake override (EBO) based on DB system
- ep-brake acc. UIC 541-6:2010
- passenger alarm signal (PAS) acc. UIC 541-6:2010
- EBO 2004 based on DB system

Please note that the ep-brake and the emergency brake override function are only allowed to be used if homologated in the corresponding country.

10.6 Indirect (automatic) brake

The locomotive provides an indirect-acting automatic brake with brake modes as defined in UIC 540:2006.

10.7 Direct (independent) brake

A direct-acting independent brake is installed. It is operated by a time-dependent control lever.

10.8 Electrodynamic brake

The vehicle has an electro-dynamic brake (ED brake) which is used preferably.

10.8.1 Rheostatic brake

A rheostatic brake is available when operating in DC networks.

10.8.2 Indications

The set and actual value for the ED braking force of the vehicle are shown on the display.

10.9 Parking brake

A pneumatic spring-loaded brake is used as a parking brake.

11. On-board power supply

11.1 AC on-board power supply

11.1.1 Three phase on-board power supply

A fixed frequency and a variable frequency three-phase on-board supply system exist to supply the electrically driven auxiliary and ancillary facilities. The fixed frequency system operates at a fixed voltage and frequency of 3AC 440 V 60 Hz. The variable frequency system operates at a variable voltage and frequency from 3AC 80 V 10 Hz to 440 V 60 Hz, to be able to vary the cooling power of the connected fans.

Both on-board power supply systems are each fed by an auxiliary inverter (AUX INV).

Disruption of an AUX INV or auxiliary transformer regroups consumers using coupling contactors on the operational AUX INV. This will then be operated with 3AC 440 V 60 Hz.

Each consumer can be separated from the circuit with an automatic protective device.

11.1.2 External supply

On both sides of the locomotive, there is a CEE mounted connector plug for the three-phase external supply 3/N/PE AC 400 V 50 Hz, 63 A. The single-phase external supply 1/N/PE AC 230 V 50 Hz, 16 A is provided by an adapter cable which is available on the locomotive.

The external supply allows the battery being charged via battery charger without overhead line voltage. The battery can be charged without enabled vehicle control.

11.2 DC on-board power supply

11.2.1 Battery and battery charger

The battery and DC on-board power supply are galvanically isolated from the AC on-board power supply by the battery charger. The battery charger charges the battery from the three-phase on-board power supply.

Additionally, the battery charger can be operated via three-phase and single-phase external supply.

The low-maintenance, sealed 400 Ah lead battery has a nominal voltage of 24 V. It is protected by two safety fuses which are easily accessible.

12. Train line

The performance data for the train line according to UIC 550:2005 are as follows:

- AC 1000 V, 16.7 Hz, max. 800 kVA (AC 15 kV, 16.7 Hz networks)
- AC 1500 V, 50 Hz, max. 800 kVA (AC 25 kV, 50 Hz networks)
- DC 3000 V, max. 800 kW (DC 3 kV networks)

Note: The operator is responsible that no short-circuits arise within the DC train line supply. The short-circuit currents harm the DC train line contactor of the locomotive. High short-circuit currents or repeated short-circuits can lead to a complete failure of the DC train line contactor.

Note: During standstill the maximum power of the train line may be restricted due to current limitations per pantograph according to EN 50367:2012.

13. Door Control Systems (TB0, ÖBB)

The locomotive is equipped with the door control system TB0 and the door control system ÖBB. These door control systems provide the release of the doors of passenger coaches, the reset of the door release or depending on the operation mode the forced closing of the doors. A side selective door control is possible only with the door control system ÖBB.

According to UIC 612-0:2009 three push buttons are provided on the driver's desk centric in front of the locomotive driver for “door release, left”, “forced door close” and “door release, right”. On the operating panels of the side control units on each side one push button “doors close” is provided.

The respective door control system can be selected via the display.

14. Train control systems

The vehicle is fitted with the following train control systems:

- ETCS (BL 3.4) Level 1 with Euroloop
- ETCS (BL 3.4) Level 2
- PZB90 / LZB80 (CIR-ELKE I)
- SHP
- LS (Mirel)
- EVM (Mirel)
- SCMT

The locomotive is equipped with ETCS in the version mentioned above compliant to UNISIG.

15. Fire safety

15.1 Standards

The locomotive meets the fire-safety requirements for the vehicle category A and B and freight locomotive according to TSI LOC&PAS:1302/2014.

Furthermore, materials are approved according to EN 45545-2 corresponding to TSI LOC&PAS:1302/2014.

15.2 Fire alarm system

For fire detection several units and areas of the locomotive are equipped with fire detectors, which are evaluated by the locomotive control system.

15.3 Fire-fighting system

To monitor and extinguish fires a fire-fighting system is integrated in the locomotive.

The fire-fighting system initiates the extinguishing process by igniting pyrotechnical triggers. The gas Novec 1230 is used for extinguishing.

The mode of action of this gas is based on removing thermal energy from the flame so that the flame extinguishes. The gas does not remove the oxygen, it is not electrically conductive and it volatilizes free of residues after the extinguishing procedure. Due to these features fire can be fought effectively without damaging other components in the machine room by water or water antifreeze mixtures. Drying or cleaning periods of several days after activation of the fire-fighting system will not be necessary.

16. Miscellaneous

16.1 Noise protection

Noise protection was given high priority when designing the locomotive by avoiding or damming of noise and vibration.

The locomotive meets the requirements of TSI Noise:1304/2014 and the noise and vibration requirements of the health and safety regulation (LärmVibrationsArbSchV 2016).

16.2 Environmental protection

Aspects such as noise protection and reduced noise emissions, use of environmentally-friendly construction materials and consumables, the ability to recycle the materials used and the reduction of materials consumed have been considered.

A mixture of normal water and glycol is used as a coolant for the traction converter. The transformer coolant is an environmentally-friendly ester which fulfils water hazard class 0 (WGK0) as defined in the General Administrative Regulation on Substances Hazardous to Water (VwVwS).

The locomotive is free of CFCs and asbestos.

Most of the locomotive's mass consists of various steel / cast materials that are easily recyclable. Other metallic (e.g.: aluminium) and also non-metallic materials (such as composites), resulting from constructive needs with the locomotive body are easily detachable so that they can be recycled separately during disassembly of the vehicle at the end of its service life. Up to 98 % of total mass are recyclable.

16.3 SIM-Cards

SIM-cards, necessary for example for the train radio, ETCS, energy meter, etc. are generally not part of the locomotive equipment.

17. Appendix A: Index of abbreviations

4QC	four quadrant chopper
ASC	automatic speed control
AUX INV	auxiliary inverter
BCH, BC	brake chopper
BCU	brake control unit
BP	brake pipe
CCD	control and command display
CCU	central control unit
CEE	International Commission on Rules for the Approval of Electrical Equipment
CH	chopper
C_{NF}	line filter capacitor
C-pressure	brake cylinder pressure
C_{SK}	resonant circuit capacitor
C_{ZK}	DC link capacitor
DB	German Railways
DC	direct current
D-end	drive side
DG	bogie
EBA	German Federal Railway Office
EBO	emergency brake override
ED-brake	electro-dynamic brake
ep-brake	electropneumatic brake
ETCS	European Train Control System
GSM	Global System for Mobile Communications
GTO	gate-turn-off-thyristor
I/O	input/output
IGBT	insulated-gate-bipolar-transistor
IT system	power system with all live parts isolated from earth (IEC 60364-1:2005)
MR	main pipe (reservoir)
MVB	multi-function vehicle bus
N	neutral phase
N-end	non-drive side
PAS	passenger alarm signal
PE	protective earth conductor
PWM	pulse-width-modulation inverter
RB	brake resistor
RDA	remote data access
RWC	rear wall cabinet
SB	emergency brake
SSP	slip and slide protection
TCN	Train Communication Network
TCU	traction control unit
TDD	technical and diagnostic display
TL	train line
TM	traction motor
TMC	time division multiplex for multitraction control
UIC	International Union of Railways
v	speed

VPI	vacuum-pressure-impregnated
WTB	wired train bus