RBDG-MAN-020-0101

Design guidelines

Railway Energy: Part 3 Non- traction power supply

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1. Regulations, Codes, Standards, and Guidelines

The internationals codes, and standards employed for the design shall include, but not be limited to, the following:

- EN 12464-1 Lighting of work places Part 1: Indoor work places
- EN 12464-2 Light and lighting — Lighting of work places – Part 2: Outdoor work places
- EN 50122–1: Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock
- EN 50122-3 - Railway applications – Fixed installations – Electrical safety, earthing and the return circuit. Mutual Interaction of a.c. and d.c. traction systems (see Note 1)
- EN 50399: Common test methods for cables under fire conditions - Heat release and smoke production measurement on cables during flame spread test - Test apparatus, procedures, results
- EN 62305-3 Protection against lightning - Part 3: physical damages to structures and life hazard
- IEC 60050: International Electrotechnical Vocabulary
- IEC 61936-1: Power installations exceeding 1 kV AC, Part 1: Common rules (equivalent to HD 637 S1 what will be replaced by EN 50522)
- IEC 60332-1-2 Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame propagation for a single insulated wire or cable - Procedure for 1 kW pre-mixed flame
- IEC 60364 series: Erection of low voltage installations (equivalent to HD 384 series)
- IEC 61936: Power installations exceeding 1 kV AC
- IEC 62305-1: Protection against lightning – Part 1: General
- IEC 62305-2: Protection against lightning - Part 2: Risk management
- IEC 62305-3: Protection against lightning - Part 3: Physical damage to structures and life hazard
- IEC 62305-4: Protection against lightning - Part 4: Electrical and electronic systems within structures
- EN 50310: Application of equipotential bonding and earthing in buildings with information technology equipment, 03/2006
- IEC 60479-1; Effects of current on human beings and livestock, Part 1: General aspects.
- IEC 61000-5-2 Ed.1:11/ 1997; Electromagnetic compatibility (EMC), Part 5: Installation and mitigation guidelines, sec. 2: Earthing and cabling
- IEC 60364-6-61:1986 (AMD1 08/1993; AMD2 08/1997, modified); Erection of power installations with nominal voltages up to 1000 V, Verification; Initial verification, (DIN VDE 0100 part 610)

Note 1: This standard shall be fulfilled when the Rail Baltica line lies in parallel with existing DC electrified railway in operation (cities approach for instance – chainages to be checked by the designer)

2. Overview and General Design Criteria

2.1. Non- traction power system NTPS for substation and parallel posts

The non-traction power supply subsystem is a part of the Railway System; as such, it shall be designed, manufactured, erected, tested and commissioned in accordance with best industry practice.

It also shall be designed using standard and proven technology and components suitable for railway standards.

These components shall be readily available throughout the world.

2.2. Design requirements

The NTPS shall be able to provide the non-traction power supply ensuring:

- The system electrical safety, including, but not limited to, grounding and bonding, clearance of leaving equipment parts, erection of safety screens, passengers and railway staff safety;
- The compliance of the system and its components with environmental conditions, including, but not limited to, temperature range, wind, humidity, rain, dust, snow storm, frost, heavy pollution, exposure to heavy vibration, shocks, seismic occurrences solar radiation found along route of the HSR;
- The NPTS shall be designed so that all components that do not differ in operational, functional, and/or performance characteristics are positioned in the same location and internal wiring is routed between components in a like manner.
- All equipment, materials, cables shall be either certified by a nationally recognized testing laboratory, or compliant with relevant International or local standards.
- All equipment, materials, cables shall be produced by manufacturers that have a proven experience in the production of such products.
- Al equipment, materials, cables shall be accompanied by the Certificates of Quality, Compliance, FAT (where applicable)

General requirement document defines value range where possible.

2.3. Safety requirements

Power Supply System shall be designed to:

- Minimize the risks regarding people and goods safety, fulfil entire staff and equipment safety during operating and maintenance,
- Prevent the possibility of dangerous interactions between systems and minimize the risks due to a wrong operation from the maintenance staff.

Any failure or wrong operating of a failsafe system or sub-system component shall not lead to a dangerous situation, but to more restrictive situations.

2.4. RAMS Requirements

The non-traction power supply shall comply with all global RAMS analyse to be submitted to the client for approval. RAMS Analyse hall be defined in the next stage of the design.

3. Facilities to be supplied by the NTPS

"NTPS Consumers" means all the facilities connected to the NTPS, classified by specialties listed in the following paragraphs.

The quantity, the location and the supply needed for each consumer must be integrated in order to define the NTPS Schematic Diagrams and its dimensioning calculations.

The non-traction power supply system is composed of diverse sources, such as:

- Medium voltage cable line installed along the track;
- Substations MV/LV;
- Local LV source;
- Transformer by means of negative feeder;
- UPS and charger system.

The sizing of MV cables and equipment related to the MV/LV system, shall be confirmed during the next steps of the project.

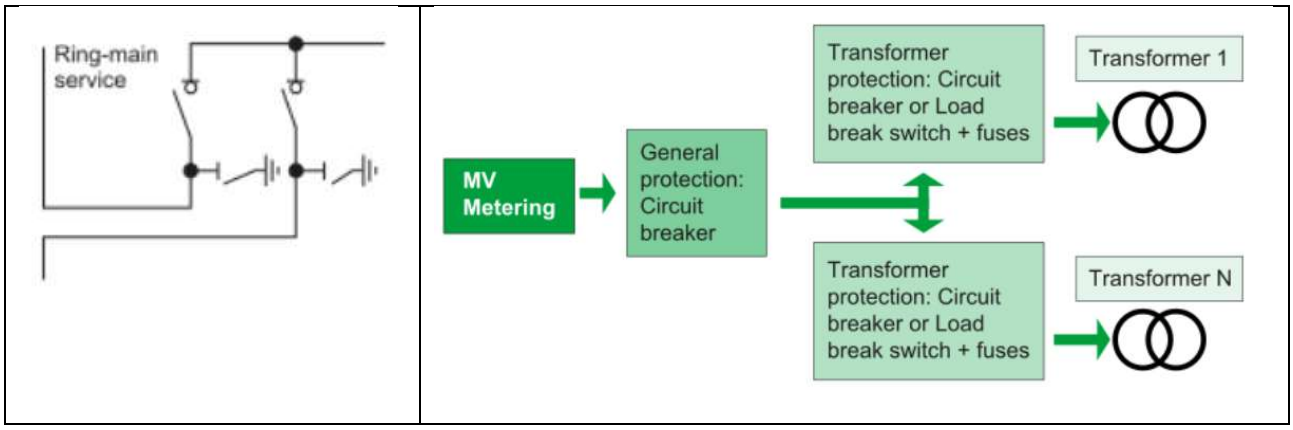
MV cables shall be buried into the ground in two specific separate paths, made in order to ensure the protection of the cables against classical disturbances (digging by shovel, ground movement, gully erosion …).

Devices to protect MV cable loop against overvoltage, such as lightning arresters, shall be provided. The protection system philosophy of MV loop shall be defined in the design phase.

The following is a proposal regarding the assembly arrangements for the MV system feeding. The following criteria should be taking into account:

In general, the MV/LV (or MV/MV/LV) substation is connected to a loop (see Fig. below on the left) of the medium voltage distribution network. The line current passes through the substation which gives the possibility to supply the substation by two separate ways. With this arrangement, the system benefits of a reliable power supply based on two redundant MV feeders. The connection is made by means of two independent load break switches, each associated to an earthing switch for cables earthing.
Substation built on site is a structure made from concrete or brick or other material suitable for accommodating electrical equipment. The typical constructive solution for an internal substation is the following (see Fig. Below on the right):

- MV switchgear consisting of a set of functional units;
  - MV cubicle for incoming/outgoing line;
  - Metering cubicle (if required);
  - MV cubicle for transformers protection
- one or more cells, equipped with walls or dividing panels and everything necessary for arranging transformers housed in prefabricated metal boxes, or else including any necessary protections against direct contacts;
- LV switchgear consisting of a set of functional units.



For every MV/LV substation, the definition of the number of MV/LV transformers takes into account the following criteria:

- Total power supplied by the substation
- Standardization of the rated power to reduce the number of spare transformers
- Limit of the rated power
- Need to separate the loads having a high level of sensitivity to the electrical perturbations
- Need to dedicate a transformer to the load generating a high level of perturbation such as voltage dips, harmonics, flicker
- Need for partial or total redundancy. When required, two transformers each sized for the full load and equipped with an automatic change-over are installed

3.1. Classification of loads

Loads are classified according to 3 types:

Emergency loads shall be connected to two separate and independent power supplies and UPS:

- Fire Alarm Control System
- Intrusion Detection System
- Control Power for TPS, including feeding of switchgear motor control
- Supervisory Control and Data Acquisition System and control power for operation of the TPS and NTPS equipment including medium-voltage and LV switchgear
- Emergency lighting in passenger stations, tunnels, emergency egress, illuminated signs and maintenance and service facilities
- Exits signs, variable message signs
- Fire protection system and public-address systems
- Control power for emergency ventilation system
- Control power for emergency communication system, and security systems

- Normal electrical power for signalling system (ATP and IXL)
- Normal electrical power for system-wide communication systems
- Emergency electrical power for the equipment at the Operations Control Centre
- Audio visual equipment for emergency exit stairs at areas of refuge
- Power to field equipment (including signaling wayside equipment) needed for life safety systems

Essential loads shall be connected to two separate and independent power supplies:

- Elevators
- Tunnel lighting normal power source
- Emergency ventilation fans and dampers
- Station duplex sump pumps
- Tunnel duplex sump pumps
- Fare collection system
- Normal power supply of the UPS systems
- Battery charger
- Heating, ventilation, and air conditioning (HVAC) infrastructure at rooms that house equipment associated with Train Control System, and Communication System.

Non-eessential loads shall be connected to one power supply:

- Normal lighting
- Escalators
- Station roll-up grille
- Equipment or other subsystems not required for evacuation or security surveillance
- General purpose and convenience receptacles at stations and along tunnels

3.2. Signalling and Telecommunication power supply

The Signalling and Telecommunication power supply system shall be able to distribute the energy along the railway in order to supply:

- Centralised signalling equipment as TMS, RBC and IXL,
- Indoor equipment for signalling as object controllers, axle counters evaluators, point heating etc.,
- Wayside equipment as point machines, auxiliary systems, point heating,
- All relevant telecommunication equipment and sites
- Auxiliary functions as:
    - Lighting in the technical buildings,
    - HVAC system of technical buildings,
    - Security systems (as intrusion, CCTV etc.).

The Power Supply system capacity shall include power reserves allowing for future system extension.

3.2.1. Power Supply source

It is essential to rely upon a secure power supply for Signalling and Telecommunication installations.

The electrical power shall be supplied preferably by the national grid system when available.

Two separate and independent power supplies shall be provided for Signalling and Telecommunication.

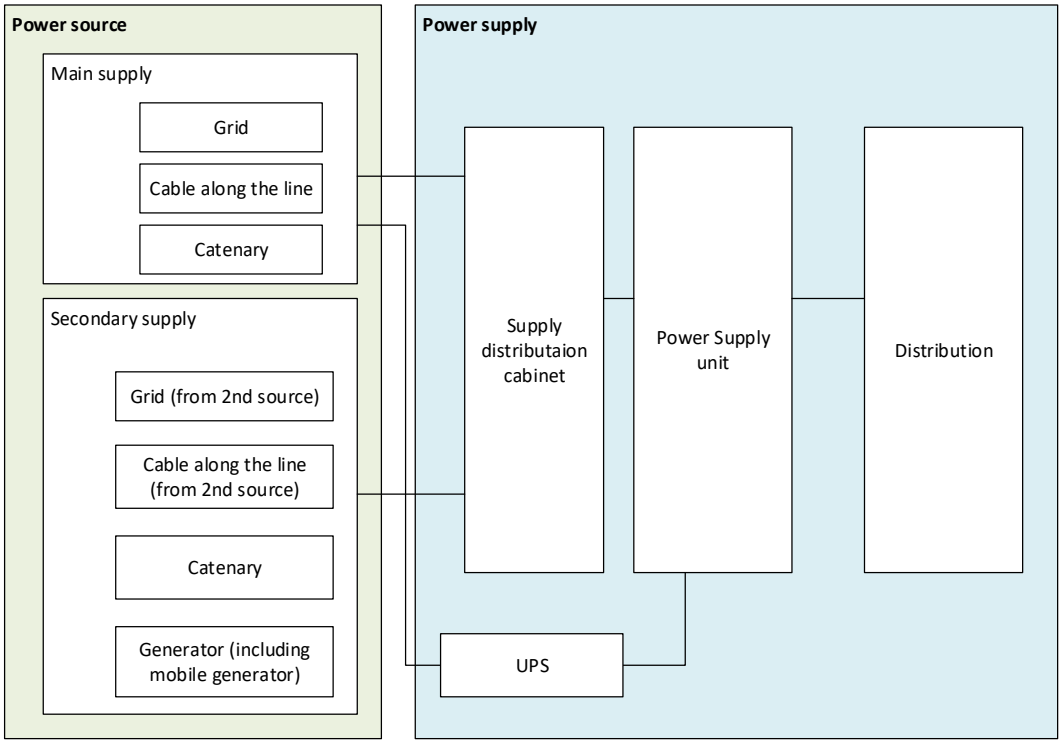
An additional uninterrupted power supply (UPS) to supply power to the electronic vital systems to ensure an interrupted power supply during switching of the secondary power supply shall be provided.

The UPS unit shall be dimensioned in order to allow signalling operation without interruption of service in case of the loss of both primary sources.

Depending on local possibilities, the following principles for power supply shall be applied:

1. Preferred connection with national grid;
2. Connection with the electric power cable along the line;
3. Connection with the catenary through a transformer;
4. Generators dedicated to the signalling & telecommunications installations;
5. Technical buildings may be equipped with a plug for mobile generator.

In general, it shall be verified if local redundant solar panel solutions or a small wind turbine could be an option.



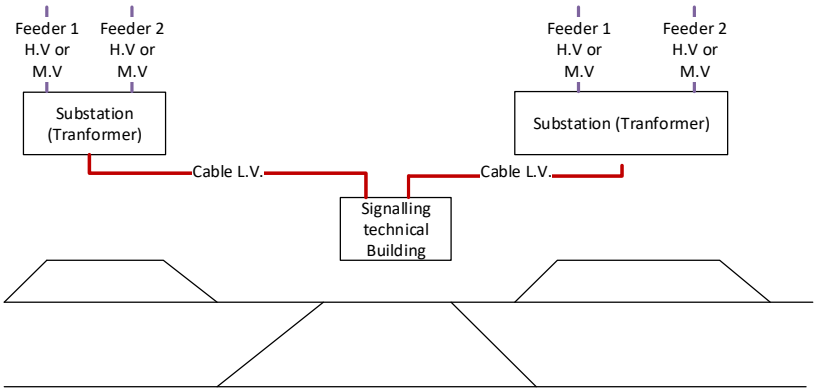
1. POWER SUPPLY SOURCES FOR SIGNALLING AND TELECOMMUNICATION EQUIPMENT

The location of the technical buildings shall be defined considering all equipment (Signalling & telecommunication) along the track to mutualize as much as possible power access point.

The selection of the source shall be ensured by Power Distribution Switches enabling:

- Automatic selection of the source feeder according to availability criteria,
- Manual selection of the source by the maintenance operator.

Example of possible sources of power supply:



2. POWER SUPPLY FOR SIGNALLING EQUIPMENT

In the case where there is no reliable supply of power, the both catenary lines shall be used as normal and back up sources. The one is to be connected through a 25kV/240V auxiliary transformers to the track UP and the other to the track DOWN. In this case the generator shall be dimensioned to be the second source of energy. These cases shall be limited as much as possible.

3.2.2. Operating time in the event of a power outage

Uninterruptible Power Supply (UPS) shall be provided for the signalling & telecommunication sub-systems including the related air conditioning systems. The UPS shall be located in shelters close to the consumption point.

In case of main power outage of the main feeder(s), the battery back-up shall be designed considering a minimum 8 hours battery backup for emergency loads for Signalling and Telecommunications systems.

In case of points machines, the battery capacity shall be designed in order to take into account the number of switch movements required during normal operation for 8 hours.

Battery required capacity can be revised upon performance by the Client of a multi-criteria analysis:

- Access time by maintenance team;
- The level of required operation (example: how many movements of the point shall be ensured by the point motor).

3.2.2.1. *UPS*

The UPS system shall be a modular scalable and shall be realized as a dual fully redundant (hot standby) true online double conversion type system.

In case one of the failure, vital loads shall be automatically switched without any interruption to the other module thus increasing the system availability.

In order to allow the maximum availability of the signalling system, the UPS shall be designed with minimum charging time. The maximum allowed charging time is 36 hours.

The UPS can be by-passed in case both UPS are in failure or subject to maintenance operation.

The UPS shall be of heavy duty manufacturing, to ensure the requested quality of service for Railway (RAMS).

The design of the UPS system meets the requirements in accordance with EN 62040-1 (safety) and EN 62040-2 (EMC).

A dedicated UPS system shall be used for telecom and signalling. Separate UPS in redundant configuration shall be provided for TMS.

The UPS shall be located in dedicated room. The connection between UPS and its battery shall be protected (by a breaker).

The temperature in this room shall be kept within the range indicated by the manufacturer in order to guarantee the operation life of the equipment. Air conditioning system can be provided to respect this requirement.

Switching between feeder A and feeder B or between feeder and UPS shall have no impact (0.0ms interruption) to the connected equipment.

The power supply shall automatically maintain and monitor the capacity of the batteries.

The SCADA shall supervise the UPS state and raised alarms.

At least the following battery states shall be monitored:

- Current operation mode (including maintenance);
- Internal UPS temperature;
- Battery charging level (including remaining battery capacity);
- Battery voltage;
- Battery ohmic;
- Battery/rectifier failure;
- Battery connection);
- Bypass state;
- Inverter faults;
- Battery Room temperature.

3.2.2.2. *Diesel generator*

In case of implementation of diesel generator, the stand-by automatic diesel generating sets shall be designed as a full operative power source for continuous operation (note: maintenance intervals every 500 hrs).

The switch-over procedure between the various power sources is interlocked to each other. This function is controlled by the local protection and SCADA equipment. The detailed procedure will be clarified during the design stage.

The diesel generator shall be specifically designed for industrial applications.

The diesel generator shall be equipped with a long-life starter battery, an exhaust air-silencer and the exhaust and supply air ducts. A power distribution and control cabinet shall be provided.

The diesel generator shall be installed in a separated room with fire-retardant walls and a fluid-resistant floor. A fuel storage reserve (fuel tank) outside of the technical building shall be defined.

The stand-by automatic diesel generating set shall be designed as heavy-duty power source for continuous operation following the required maintenance intervals. The rated output power of the diesel generator shall consider the local environment conditions, the dynamic load cycles and the power disturbances of various kind consumer loads.

Diesel generator shall be of fully autonomous type, capable of automatic and/or remote startup/stop. If installed in compartments without heating, it shall be capable to start at the minimum ambient air temperature (defined in General requirements) or shall include automated and/or remote-controlled preheating solution to ensure startup of the generator.

3.2.3. Earth leakage detection

The technical buildings shall be equipped with an earth-leakage indicator to monitor the insulation of the active conductor towards earth.

A single earth fault is indicated by an audible and/or optical signal. The first ensures a higher electrical safety. This enables continued operation and consequently higher availability but requires repair before a second earth fault occurs.

3.2.4. Expandability

For future extensions a load power reserve of 20% shall be provided.

Space for expansion of the switchgear shall be considered in the layout of the buildings.

3.3. Terminal and intermediate stations and Technical stops

Terminal and intermediate stations shall be connected to the national grid in compliance with EU standards and national standards.

3.4. Lighting requirements

The lighting design shall be compliant with:

- EN 12464-1 Lighting of work places Part 1: Indoor work places
- EN 12464-2 Light and lighting — Lighting of work places – Part 2: Outdoor work places

3.5. Traction substations and posts auxiliaries' facilities

The traction substation auxiliary facilities are normally supplied by specific auxiliary transformers, which form part of the traction substation.

In the event of outage of the High voltage line feeding the substation, supplies may be secured by a back-up.

This back-up could be provided by the MV line along the track or a local low voltage source.

The primary auxiliary power source shall be switched to the others auxiliary sources via an automatic transfer switch.

The auxiliary transformer shall be sized based upon the demand electrical load.

Auxiliary transformers may be indoor or outdoor with suitable enclosures according to their location.

An emergency power source (i.e., battery and charger system), rated for at least 8 hours connected electrical load, shall be provided for all emergency loads. In addition to the noted electrical loads, the emergency power source shall be able to support at least 2 operating cycles (where trip and close operation constitute 1 cycle) of all circuit breakers and 1 operating cycle of switches.

The design of the batteries shall consider a life expectancy of at least 20 years, and be low maintenance.

Transfer from the normal LV power source to the emergency power source shall be automatic.

The simplified non- traction power supply system for different posts and substations are shown in figures 1 and 2.

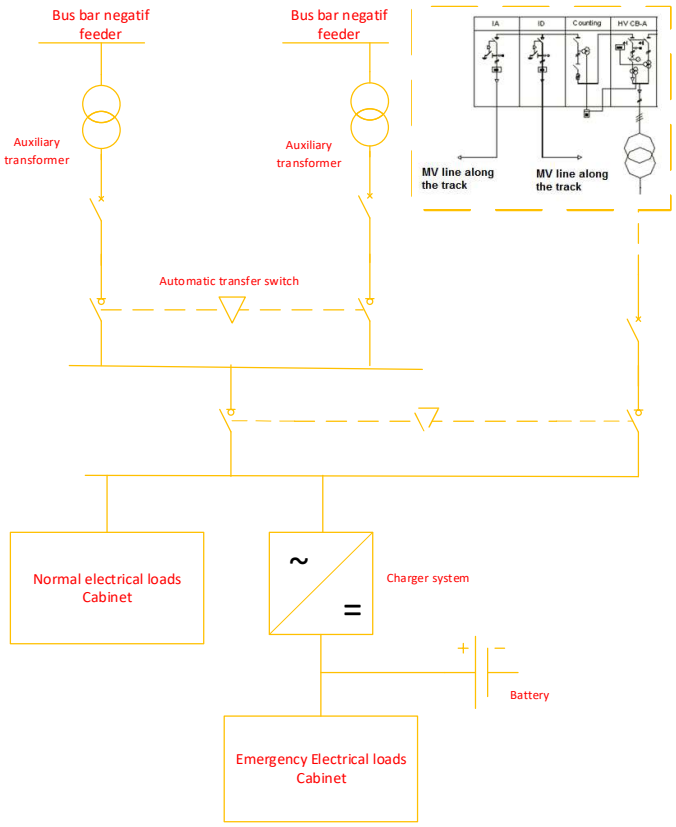


Figure 1 – Schematic non- traction power supply for substation and switching post

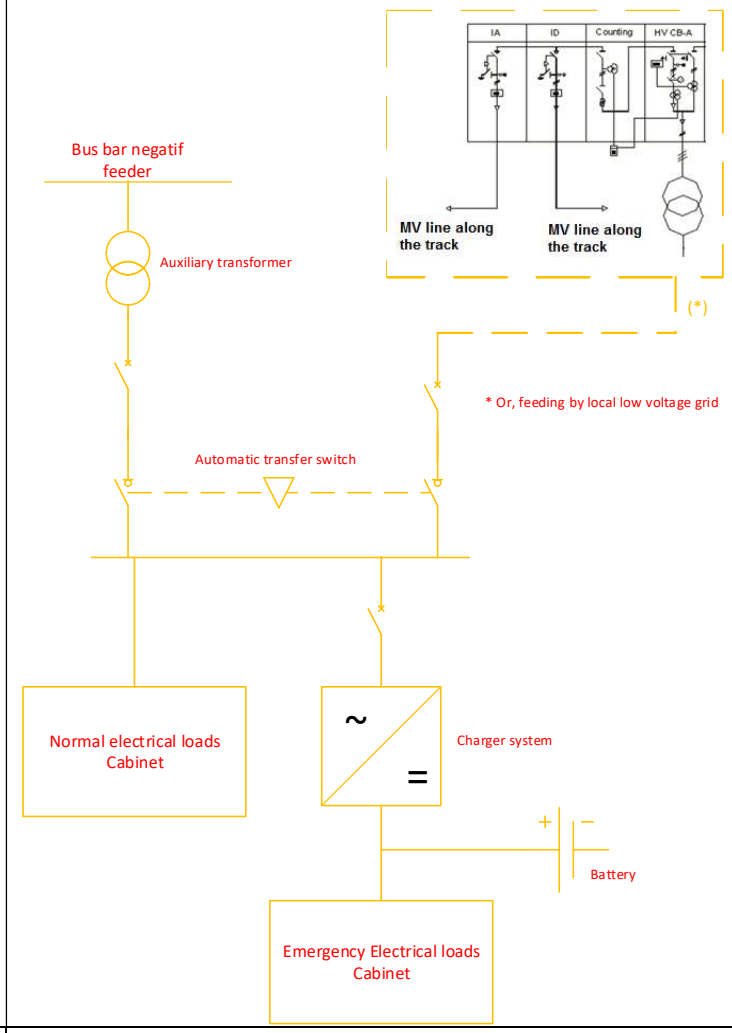


Figure 2 – Schematic non- traction power supply for Parallel post

4. Safety of the NTPS facilities

4.1. Principle of Safety

The non-traction power supply shall be designed, constructed, installed, commissioned and tested to ensure the safety of the staff, passengers, and public under all normal operating and fault conditions.

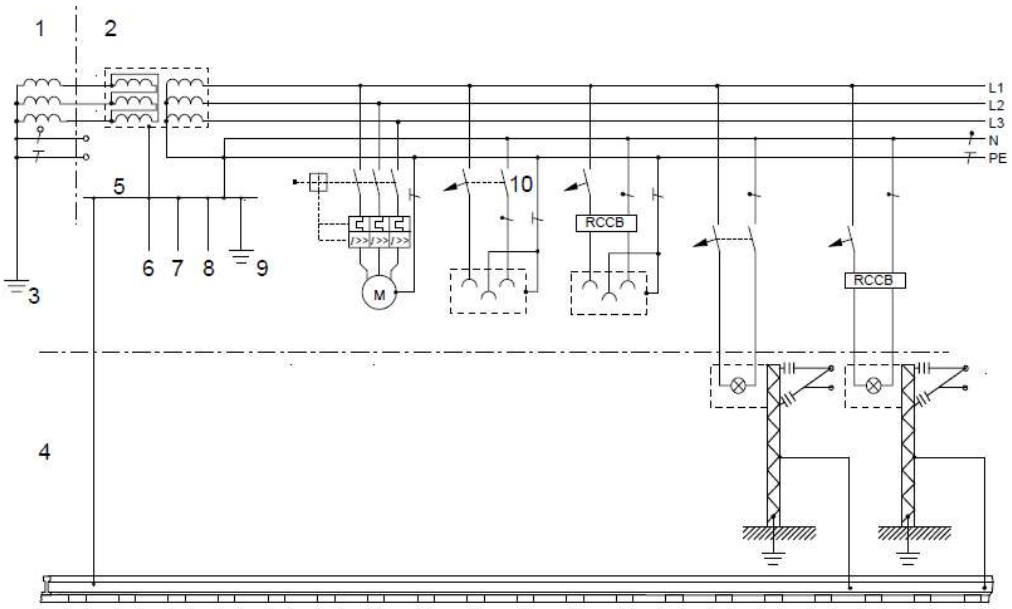
4.2. Earthing and bonding

The construction of railway installations generally requires a concept for earthing and bonding including provisions for lightning protection for the involved parties in the project. This is important particularly for modern systems with high traction currents and the extensive use of electrical energy for many purposes.

The objectives for earthing and bonding are:

- The safety of persons - The safety of persons is characterised by the value of the touch voltage.
- The protection of installations - Damage of installations may arise from overheating of conductors, by arcing.
- The intended operation of the system - For the intended operation of the system the aspect of electromagnetic compatibility (EMC) has to be considered too.

Grounding and Bonding provisions shall be in compliance with EN 50122-1 Railway Standard, as well as EN 50122-3 when located adjacent to operational DC electrified railway.



Key

1	electricity supply network	6	water and gas pipes
2	railway network	7	heating
3	public earth	8	lightning protection
4	overhead contact line and current collector zone	9	railway structure earth
5	MEB	10	only required for rail potential > 50 V

RCCB = residual current operated circuit-breaker without integral overcurrent protection

MEB = main equipotential busbar

M = Motors

L1 L2 L3 = Phase conductors

N = Neutral conductor

PE = Protective conductor

The design of earthing and bonding conductors with respect to the safety of persons includes the protection of installations under normal and fault conditions. Additionally, the requirements for the protection of live parts against overheating for normal operation and during fault conditions have to be fulfilled. The standard series HD 60364 applies.

4.3. Interlocks

All appropriate equipment shall be fully interlocked to ensure its own protection and staff safety.

Interlocks shall be designed in order to allow the use of padlocks to switch devices in insulated/earthed position.

The different power supply sources (main and emergency power) shall never be mixed.

4.4. Lightning protection

An assessment of the risks presented by lightning shall be carried out in accordance with the standards of series EN 62305. If necessary, a lightning protection system shall be erected.

Overvoltage of atmospheric origin transmitted by the overhead supply system shall be taken into account when the installation is designed.

Equipment and receivers shall not be subject to voltages exceeding their lightning impulse withstand levels.

Particular attention shall be paid to the impedance of the earthing connection of the lightning arresters, which shall be as low as possible in order to avoid reducing their effectiveness.

Particular attention shall be paid to the Scada System, in order to protect all sensitive equipment by overvoltage disturbances.

Power conductors shall be protected from lightning with grounded shield wire(s), hanging over, to minimize effects of flashovers and subsequent short circuits or other defects.

Buildings, outdoor installations and other structures endangered by direct lightning strikes require an external lightning protection system according to the standard series EN 62305-3.

Internal lightning protection is the protection of equipment against the danger of damage by overvoltage and partial lightning currents caused from lightning strikes. The limitation of voltage is achieved by means of consequent bonding and by surge protective devices.

4.5. Fire protection

The design of all the NTPS System equipment shall be provided to minimize effects and spread of fire.

Detailed requirements are in RBDG-MAN-012 general requirements.

4.6. SCADA

Please refer to RBDG-MAN-024 Railway SCADA.

4.7. Spares

The following spares requirements shall be incorporated into the design. The design shall include electrical distribution capacity, space for future circuit breakers, and rough-in raceway systems to permit future equipment placements.

- Switchgear, switchboards, and panel boards shall be equipped with a minimum of 25 percent spare circuits and bus capacity. Standard size equipment shall be used.
- The design of the Interface Termination Cabinet shall include at least 25 percent spare termination hardware.
- At least 25 percent or 1 spare duct (whichever is greater) per voltage level/system shall be provided in all interbuilding underground duct bank runs.
- At least 25 percent or 1 spare conduit (whichever is greater) per voltage level/system shall be provided in each conduit run.
- The total section occupied by the cables, including all protections, shall be no greater than 40% of the internal cross-sectional area of the conduit for a three-core cable and 30% for several single-core cables.

4.8. Cable Separation Criteria

The conditions for installing an electrical wiring system in proximity to a telecommunication line or a pipe carrying water, hydrocarbon, gas, compressed air, steam, etc. shall be determined in such a way as to ensure that the phenomena of electromagnetic induction, electrical influences and accidental or permanent rises in potential caused by the electrical wiring system cause no hazards or disturbances to neighbouring installations. The importance and consequences of these phenomena shall be subject to specific studies specifying the provisions to be taken to protect against them. The influence of neighbouring services and structures on electrical wiring systems shall also be taken into account, particularly where temperature rises are concerned.
Cables in the same cable category may be run together in the same steel conduit, raceway, duct, trough, manhole, or cable tray, if all cables that are grouped and run together are insulated to the highest voltage level present in the group.
Cables in different cable categories shall not be run together in the same cable assembly, conduit, raceway, duct, or cable tray, without engineering justification documenting the specific cables, signals, and protections against EMI for the proposed combination. However, optical cables may be run together with any other cable.

4.9. Calculations

4.9.1. Voltage Drop

The following voltage drop criteria shall be applied.

- Sensitive Electronic Equipment
    - 1.5 percent or less on branch circuit conductors
    - 2.5 percent or less on combined feeder and branch circuit conductors
- Power and Lighting Circuits

  - 3 percent or less on feeder circuit conductors at the farthest field device in the circuit
  - 5 percent or less on combined feeder and branch circuit conductors at the farthest field device in the circuit
- Tunnel Ventilation Fan Motors
  - 10 percent or less on feeder circuit conductors to fan motor during initial start-up conditions
  - 3 percent or less on feeder circuit conductors to fan motor during steady state conditions
- LV Motors
  - 10 percent or less on feeder circuit conductors to LV motor during initial start-up conditions
  - 3 percent or less on feeder circuit conductors to LV motor during steady state conditions
- Emergency Standby Generator System
  - 5 percent or less on feeder circuit conductors to the LV switchboard during initial start-up conditions
  - 3 percent or less on feeder circuit conductors to the LV switchboard during steady state conditions

4.9.2. Demand and Diversity factors

Demand and diversity factors shall be defined by the designers according to the best practices.

5. Verifications, tests and acceptance requirements

The operational capabilities of the proposed NTPS facilities shall be demonstrated, for normal and backup operating.

It shall be provided a testing and commissioning plan with detailed method for each of all the testing and commissioning processes carried out.

The testing and commissioning shall be undertaken in accordance with the requirements of NTPS's design.

The entire acceptance criteria for the NTPS will be, at least:

- The satisfactory completion of the testing and commissioning program;
- A complete final examination of the facilities, which shall meet the requirements of NTPS's design;
- The completion of all process needed by the training, documentation, and maintenance requirements.