

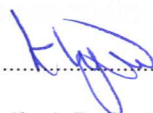
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Business Process Document

Guidance Note for Signalling Power Supply Design

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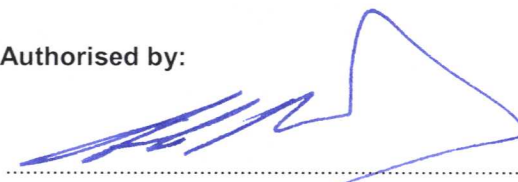


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1 Purpose

This Guidance Note provides advice to Network Rail engineers, principal contractors and designers on the design of signalling power supplies for railway infrastructure. This principles contained within this guide should be applied to any signalling supply installation.

This guide will not relieve any party of their duties under the CDM regulations.

Although aimed at signalling power supply systems much of the advice applies to any safety critical loads and the principles can be applied to any electricity distribution system.

2 Fundamental Requirements

Certain fundamental requirements apply to the design of signalling power supplies:

- a) Power supplies should be sufficiently reliable to provide availability of the load so as to minimise the probability of failure to signalling systems;
- b) The most practical distribution voltage should be utilised and LV is preferable to HV. Where practicable, industry standard voltages should be considered;
- c) Design of non-earthed distribution systems should include a continuous insulation monitoring regime and implementation of a procedure for fault location and management;
- d) Signalling equipment requires an earth free supply;
- e) Maintenance requirements should be established for each system and implementation agreed with the maintenance organisation;
- f) Where the proposed maintenance regime requires isolation of the signalling system a possession plan should be established. This may require revision of the rules of the route and should include agreement on action to be taken if maintenance tasks are re-scheduled;
- g) Redundancy and automatic reconfiguration should be considered unless the availability requirements of the most critical load demonstrate this to be unnecessary;
- h) Where automatic reconfiguration is not required, the level of redundancy required should be established unless the accessibility for maintenance is provided in accordance with clause g ;
- i) Where possible, industry standard equipment should be utilised.

3 Historical Background

Power to the trackside signalling equipment has been provided using a consistent design which was originally introduced in the 1920s.

Key characteristics of the system are:

- 650V trackside distribution system;
- 2-wire, earth-free (nominal IT) operation;
- Long, single, radial feeders, with limited interconnectivity;
- Use of float power-supplies to facilitate sporadic, high, short-term demand;
- Diesel Generators providing an alternative source to the DNO;
- Standby supplies typically DC from large banks of secondary cells.

Note: Some ring feeder systems do exist that provide limited diversity of supply however these are in the minority.

Increasing performance demands upon the infrastructure has resulted in a number of deficiencies becoming apparent. These include :

- Inadequate system protection;
- Inadequate system discrimination;
- Complete system isolation under fault conditions;
- No alternative supply on simple radial feeders under open-circuit cable fault conditions;
- Difficulties with identification of faulty equipment;
- Limited maintainability without isolating load;
- Poor Voltage Regulation;
- No application of diversity factors resulting in load over-estimation

Failure to assess the overall performance impact when new loads have been connected to an existing system has resulted in over-stressed networks with poor voltage regulation and limited capacity to cope with transients.

For any future signalling scheme the power supply system should be capable of meeting the demands for the anticipated life of the scheme whilst being safe to operate, maintain and repair.

4 Application Considerations

An appreciation of the consequences of signalling power supply failure is useful. Additionally, some of the background information in relation to the design philosophy for signalling power supplies is introduced here.

4.1 Signalling Equipment

Principal components are track circuits, signals, points, interlocking, axle counters and TDM modules. A more complete list of equipment which may be powered from a trackside distribution system is listed in Appendix A.

4.2 Power Supply Failures and Consequences

Signalling power supply failure can have a significant effect on performance and safety, dependent on the type, duration and extent of the disruption.

Whilst signalling equipment will generally fail safe if the power supply is removed, secondary hazards become more prominent because a higher risk system is used to control train movements.

Loss of supply to signalling equipment can result in the following:

- Black Signal (signal showing no aspect);
- Point Equipment Failure;
- Signalling Control Centre Blackout;
- Loss of Track Circuit Status (Signalbox Indications);
- Loss of Signal Status (Signalbox Indications);
- TPWS (Train Protection Warning System) Failure.

Consequences include:

- Inability for the signaller to determine train location;
- The need to resort to a procedure-based train control system (e.g. hand signalling, higher risk than automated signalling control);
- Train Delay.

Poor power quality can result in:

- Disconnection of Supply following protection operation (Transient);
- Data errors on SSI or similar software based signalling systems (Harmonics).

4.3 Power Distribution

Power distribution for trackside equipment is characterised by small loads at relatively long distances from the supply.

High voltages are utilised by DNOs for distribution over similar distances to minimise voltage drop and provide sufficient fault current however the cost of supply points becomes prohibitive for the large number of feeds that are required for many signalling systems.

The advantages and disadvantages of using LV over HV are listed below:

Advantages:

- Closer to utilisation voltage;
- Fewer procedures for operation;
- Less complex maintenance;
- Cheaper equipment.

Disadvantages:

- High system impedance;
- High source impedance;
- Poor voltage regulation;
- Low fault currents;
- Larger conductor sizes;
- Protection harder to co-ordinate;
- More complex design process.

The source impedance for such distribution systems may be extremely high due to the use of UPS equipment and weaker DNO supply systems used in rural areas.

Due to the high source impedance the earthing system design has to be carefully co-ordinated so as to ensure sufficient fault current will flow for the protection devices to operate effectively.

The Electricity at Work Regulations (EAWR) 1989, apply to all installations. Engineering using the framework described within BS 7671 is necessary to demonstrate compliance with the regulations.

In addition to compliance with the EAWR which is a fundamental requirement for safety, the system has to be specified to take account of the reliability and availability required of the overall signalling system.

4.4 Design Process and Project Life Cycle

A flowcharted design process is outlined within Appendix B.

The flowchart identifies the major stages within the process and shows some of the data required and the decisions that need to be made in order to select the system voltage, topology, earthing and bonding requirements.

This process should be used at the Pre-feasibility and Option Selection stage of a project in order to select the correct solution.

Appendix C outlines the development stages of the single option development and detailed design stages of a project. The key outputs that would be required to demonstrate the design process are also identified.

More detailed descriptions of parts of this process are shown in sections 5 to 9.

5 Load Scheduling

The first stage of any electrical system design is to identify the loads to be supplied. In order to achieve the correct assessment of the loads the following stages should be carried out:

- Classification of Electrical Loads;
- Load Location Identification;
- Equipment Operation Assessment/Signal Engineer's Requirements;
- Electrical Diversity Calculation.

Each of these is now described in turn.

5.1 Classification of Electrical Loads

The Signal Engineer should first identify the type of system to be utilised e.g. track circuits or axle counters, lamps or LEDs. The signalling equipment supplier will be able to provide advice on the rating of each individual piece of equipment which should include power, power factor, inrush current etc.

A number of different pieces of equipment may be associated with a particular location case or functional supply point. In order to assess the load, the equipment connected has to be adequately described. It is not sufficient just to use the current rating of the fuse which is protecting the equipment(s) as this will very quickly result in substantial over-rating of distribution equipment as such a rating is almost never representative of the load.

All equipment should be capable of accepting a supply, which varies within the tolerance bands laid down by the DNO. Any equipment that cannot operate across these ranges will require special dedicated supplies that have been suitably conditioned by UPS or similar. During the assessment of individual loads any pieces of equipment which have special supply requirements should be identified.

5.2 Load Location Identification

Once the individual loads have been identified then their locations should be established so as to facilitate correct selection of the topology of the distribution system. For railway applications identification of location is critical due to the assessments that need to be made of supply availability and feeder lengths.

5.3 Equipment Operation Assessment/Signalling Engineers' Requirements

An understanding of the normal operation of the signalling will facilitate the correct assessment of the loads. Whilst colour light signals may operate continuously, items such as point motors will operate intermittently. Thorough analysis of the operation of the routes to be set etc. will allow an assessment to be made of the loads which will operate concurrently.

Information on the operational requirements of the signalling equipment has to be sought from the Signal Engineer.

The information that would be required will include:

- Voltage requirement and tolerances;
- Frequency requirement and tolerances;
- Harmonic requirements and tolerances;
- Supply interruption tolerances;
- Inrush current requirements.

During this process an assessment should be made of prospective future load growth which may occur along a route as a result of additional signalling equipment.

5.4 Electrical Diversity Calculation

Once the load location, grouping, and operation are understood then a clear description of the load requirements may be made. A diversity factor should be applied to the total power consumption expected from individual loads or groups of loads. This will reduce the load which will be catered for within the design from the rated demand to the maximum operating demand. The diversity factor will be set based upon the equipment operation assessment above.

5.5 Produce Load Schedule

To produce a load schedule the following should be established for each circuit:

- Average Demand (kW, kVAr);
- Maximum Demand (kW, kVAr);
- Inrush Current (Amps);
- Power Factor;
- Voltage Tolerances;
- Frequency Tolerances;
- Distortion Tolerances (THD).
- Type of equipment: number fitted and number used for load calculation.

Care has to be taken throughout the process to ensure that load margins are not compounded during the design resulting in over-specification of the system.

6 Selecting Power Supply Configuration

Once the requirements of the load have been established, the distribution system configuration may be selected, in accordance with NR/SP/ELP/27243.

However, each of the following areas should be considered in turn in order to successfully produce a detailed design of the selected system for a particular application:

Power supply quality criteria;
 Reliability, Availability, Maintainability, Safety (RAMS) Targets;
 Distribution system phase number and voltage options;
 Earthing arrangements;
 Protection/sectioning arrangements;
 Supply source configurations;
 Network configuration options;
 Remote monitoring options.

6.1 Power Supply Quality Criteria and RAMS Targets

Completion of the load schedule should identify the power supply quality criteria to be applied to the project. The requirements of the most sensitive piece of signalling equipment should be catered for.

Where a project utilises the requirements within NR/SP/ELP/27243 the performance requirements of the system are considered to have been met.

If a project decides to deviate from NR/SP/ELP/27243, i.e. develop a solution based upon particular RAMS targets, then a reliability study will have to be performed in order to check that the system will meet the requirements. This study then acts as the supporting evidence in the derogation application to NR/SP/ELP/27243.

The method for calculating RAMS targets is described in BS EN 50126.

The quality criteria and RAMS targets will decide if UPS equipment should be utilised and the level of redundancy required.

6.2 Distribution System Phase Number and Voltage Options

NR/SP/ELP/27243 requires 650V single-phase a.c. to be utilised for major re-signalling schemes. Unless a RAMS analysis demonstrates otherwise, all systems should initially be designed on the basis that they will be IT.

For a major re-development of an existing system, if it becomes apparent that a 650V single-phase a.c. distribution system is not feasible, an assessment should be made as to which industry standard voltage to utilise. Possible options include:

- 650V Three Phase;
- 400V Three Phase;
- 400V Single Phase;
- 230V Single Phase.

Selection will depend upon the frequency and magnitude of loads and to a lesser degree on the availability of supplies.

Modification of an existing 650V single phase system should not result in any change in voltage.

6.3 Earthing Arrangements

Traditionally, the complete signalling power supply system has not been earthed. This has the advantage of increasing the systems tolerance to faults but the disadvantage of a more complex design and operation.

The exact earthing and bonding arrangements will depend upon the proximity to AC and/or DC electrified lines. When designing the earthing system the following aspects should be considered;

- AC Electrification proximity (bonded to traction return);
- DC Electrification proximity (equipotential zones and bonded to local earths);
- Induced voltage effects;
- Potential Rise under fault conditions;

- Ability to carry fault current;
- Bonding;
- Interference with signalling equipment;
- Interference from Traction Supplies;
- Lightning Protection;
- Switching Transients.

RT/E/S/21085 and RT/E/S/21032 provide detailed information on earthing and bonding around electrified lines. RT/E/G/00004 provides additional support.

6.4 Protection/Sectioning Arrangements

When designing the system, consideration has to be given to the placement of protective devices within the network to ensure disconnection under fault and overload conditions; and to protect against electric shock.

Effective protection discrimination is necessary across the network (from supply intake point to trackside signalling equipment) in order to ensure the minimum disruption in the event of disconnection of the system. With the traditional 650V system operation of a protective device would result in the complete failure of that section of the distribution.

Protective devices such as fuses, MCBs and relay driven MCCBs should be carefully selected and electronic protection should be considered. Fault currents will very often be limited by high impedance sources such as UPS equipment and long cable runs.

Before protective devices can be selected an assessment should be made of the fault currents and voltages that will be seen within the system. This may be complicated by the proximity to a.c. and d.c. electrified lines. This assessment is vitally important to ensure that the system is both safe and reliably protected.

In order to assess the protection a series of co-ordination curves are produced which demonstrate how the protective devices discriminate with each other. Details of each of the protective devices used and their settings are gathered and then plotted. The output of the study should include time/current graphs of the operating characteristics of the fuses/MCBs/Relays referenced to one voltage. This will clearly reveal the discrimination between devices and any potential conflicts. The graphs should also be marked with the maximum prospective fault currents at each stage in the system.

Automatic sectioning equipment may be required in order to restore supplies if one feeder fails. Care should be taken to ensure that the operating logic of the sectioning equipment meets the requirements of the system and that the system will cope with feeding in more than one direction.

6.5 Supply Source Configurations

Electricity supplies for each PSP may be drawn from a variety of sources, which include:

- DNO LV or HV systems;
- Network Rail 11/6.6kV Distribution Ring;
- Diesel Generator;
- 25kV Traction via Transformer;
- 33kV Traction via Transformer.

As a minimum where two supplies are provided then a changeover system should be provided. Where the load demands a certain supply quality or the system demands specific availabilities, then UPS equipment should be installed. Introduction of such equipment will present additional problems including protection co-ordination.

6.6 Network Configuration Options

Network configuration options that should be considered during the preliminary design stage are described in NR/SP/ELP/27243.

The majority of existing systems are simple radial feeds. These are potentially the lowest reliability systems, as a fault will isolate a quantity of equipment with no hope of restoration, unless the system is automated. These systems cannot be interconnected.

A number of techniques may be employed to improve the availability of the system and these include the introduction of automation to reconfigure the system but moreover a change in the topology to one of those listed above.

For high availability systems, some form of changeover facility may be provided at the FSP. Contactor, MCCB, dedicated changeover switch or static switch may perform this function.

The system topology will, in part, be defined by the need for access to perform maintenance. Where possession time is at a premium or unavailable and the rules of the route cannot be changed to allow for maintenance time, the facility should be built into the system to allow testing and repairs to be performed, whilst the system is operating.

Over-estimation of the number of outages required to perform maintenance may lead to wasted possession time whilst under estimation may lead to missed maintenance and eventual isolation of the system.

Equipment selection should take account of maintenance requirements that are identified during the design, involvement of the region and its maintainers at the earliest stage possible will reap the maximum benefits.

6.7 Remote Monitoring Options

As the performance requirements for the distribution systems increase and the complexity of the sub-systems increases then there is a greater need for monitoring to allow the correct action to be performed in the event of failure.

Note: A clear business case should be developed to demonstrate the benefits of any proposed application of RCM.

The development of requirements for RCM should address the following points:

- the RAMS targets which may demand response in a certain time which may only be achieved through monitoring;
- local operating practices which require certain parameters to be monitored in order to achieve consistency with other sites;
- requirement for monitoring of certain equipment e.g. UPS.

6.8 System Configuration Study

Once all of the above areas have been considered and the topology of the distribution system decided, a statement should be produced to describe the design, the reasoning behind the selection and any assumptions made. For complex or novel systems a number of different configurations may need to be proposed and the solution agreed with Network Rail.

6.9 Electromagnetic Compatibility Study

BS EN50121-5 describes the requirements for electromagnetic compatibility that should be applied to fixed signalling power supplies. As part of any system design the effects of electromagnetic interference should be considered.

Where novel equipment is being installed then an assessment should be made of the changes in emissions and susceptibility and their consequences.

7 Performing Detailed Design

7.1 Design Calculations

Once the Network Rail has accepted the system topology (Form EA - NR/SP/ELP/27311) then the detailed design may be compiled.

Dependent upon the system some or all of the following calculations would need to be undertaken:

- Fault Levels (Phase to Phase/Phase to Earth/Earth);
- Voltage Regulation;
- Transformer Rating;
- Transformer Regulation;
- UPS Rating;
- UPS Battery Rating;

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Inrush Currents;
Harmonic Penetration;
Induced currents from Electric Traction System Faults.

This list is not exhaustive. An example of how fundamental design calculations could be carried out is provided in Appendix D.

Some or all of these calculations may need to be performed in parallel with equipment selection as described in section 7.3.

7.2 Grouping of Loads

During the detailed design phase an assessment should be made of the clustering of signalling equipment and the most effective way that the equipment can be supplied. To achieve this, a balance should be struck between minimising the number of functional supply points and ensuring that in the event of partial or total failure of the system the minimum disruption is caused. Consideration of these degraded modes will ensure that in the event of a failure the signaller will be presented with the minimum disruption and also may be able to run a reduced service. This is especially important where three phase systems are being utilised as the loss of one conductor should not result in a complete suspension of service.

7.3 Selection of Equipment

Once the system has been designed, suitable equipment should be selected. For safety related equipment the only products which have or are being assessed through the acceptance process should be considered.

For the remaining equipment care should be taken to ensure that what is selected will meet the whole life requirements of the installation. Where possible equipment should be drawn from industry standard ranges rather than bespoke manufactured.

Special attention should be paid to the protection devices to ensure that they will operate as expected and provide a range of settings, which will allow discrimination.

A range of equipment and the key characteristics that should be considered for each item is listed in Appendix E.

7.4 Distribution System Design Documents

Once the calculations have been finalized using accurate data from the selected equipment then a System Design Document should be produced which describes the proposed network as it will be installed.

The information produced should be as accurate as is possible at the time with any assumptions or historical data used being clearly stated.