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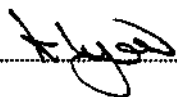
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Business Process Document

Guidance Note for Uninterruptible Power Supply (UPS) Equipment

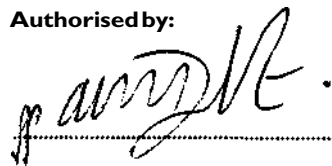
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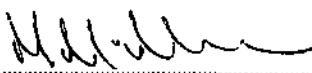
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1 About this Guidance Note

This Guidance Note is intended to advise Network Rail staff about the principal considerations regarding the application of Uninterruptible Power Supplies (UPS) for railway infrastructure. The guide is aimed at UPS systems with a rating of 20kVA upwards for signalling installations however, much of the guidance is applicable to smaller units and other installations.

2 Background

Network Rail has many applications for UPS equipment across different assets and voltage ranges. For most applications, equipment operating at standard industrial voltages such as 400V three phase or 230V single phase in varying combinations of stand alone, parallel and alternative supply system configurations is usually adequate. Some will require input/output transformers to achieve the required voltage levels, such as 110V. Network Rail's distribution systems contain many features, which will result in consideration having to be applied to each installation.

Network Rail has specialised needs such as 650V single phase UPS equipment to support signalling supplies at track-side locations and UPS equipment supplied from 25kV AC Overhead Line Equipment. These solutions combine to support the needs of new and existing UPS applications, whilst complying with HQ's policy on LV power supplies.

UPS equipment for Network Rail is specified in Business Process Product Specification [RT/E/PS/00007](#) – Uninterruptible power supply units for operational infrastructure. In addition, all UPS equipment for signalling supply applications must be approved through the Product Acceptance process.

3 Basic Concepts

The main function of UPS equipment is to provide continuous electrical power to business critical systems or equipment, irrespective of the source supply condition. This is achieved through the use of power electronics and a battery system. A feature of this process is that the UPS equipment can improve the quality of the supply waveform to the load. The incoming waveform can be distorted by other customers' equipment on the power supply network, thereby introducing possible failure of Network Rail's equipment.

During failure of the normal supply therefore, the UPS supports the critical system until such time as the alternative supply is available or normal supply is restored. The UPS will only provide power for a limited duration, which is defined by the size of the battery. For most railway applications, a minimum runtime at full load of 10 minutes will be specified, as this will provide sufficient time of the alternative supply to be made available. Regular maintenance of the UPS and especially the battery system is necessary to ensure the continued functionality of the equipment.

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The a.c. source supply is passed through an electronic conversion process, which is combined with a battery system to produce a continuous and regulated output. This can be achieved through configurations such as “off line”, “line interactive” or “on line”, which are chosen to suit particular applications. For almost all applications “on line” power conversion should be used.

To accommodate fault conditions or abnormal operation, UPS equipment is fitted with an internal electronic static bypass switch. This serves to rapidly isolate the power electronics until normal conditions are re-established. To allow maintenance activity to occur without loss of supplies, an external manual maintenance bypass facility should be supplied for all critical power applications.

Two technologies exist within “the on-line” category, double conversion and delta conversion. Applications for both of these technologies are considered within the document.

Regular maintenance of UPS equipment is essential as the batteries the equipment relies upon to function in the event of power failure are perishable.

4 Safety Considerations

As part of the Network Rail Line Standard preparatory work, Hazard Identification (HAZID) studies have been performed with Network Rail engineers and suppliers to identify which risks could not be tolerated by the railway infrastructure as a direct consequence of the use of UPS equipment. The principal risks identified were as follows:

No.	Risk Subject
1	Harmonic rich UPS output
2	UPS Interferes with DNO Supply
3	Hazardous materials used
4	UPS installed in an unsuitable environment
5	Component failure
6	Systematic hardware failure
7	Failure due to software
8	Untrained staff
9	Inadequate monitoring and indicating functions
10	Tampering with UPS
11	UPS restarting after fault onto exposed conductors.

To achieve compliance to the Network Rail Line standard, risks 1, 2 and 3 can be mitigated by most suppliers, through use of a product from their standard product range, supplemented with an independent output voltage/frequency/distortion monitor.

One of the principle risks associated with the loss of signalling power is a Category “B” technical SPAD. The failure of the signalling power supply for any extended duration will result in loss of indication and a cessation of services with the obvious performance impact.

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There are however risks associated with short duration interruptions to signalling supplies and poor power quality. Both of these phenomena have the potential to disrupt the normal operation of signalling equipment.

5 milliseconds are regarded as the maximum period equipment may be without power before failure occurs so this is the longest duration allowed before the supply is restored. Excessive harmonics can also affect signalling systems. As a result, there is a requirement that UPS equipment should limit its output voltage total harmonic distortion (THD) to less than or equal to 5%, when measured over the first 20 orders of harmonics and to less than or equal to 4% measured over the 3rd, 5th. and 7th. harmonics. These are considered to be the maximum levels that an acceptable machine may operate at.

Each project will have to take the advice supplied by the Signalling Engineer on the frequencies being utilised by the particular equipment to ensure that none of the UPS output harmonics will affect the signalling systems.

Other potential failure modes may be eliminated through detailed design of the installation utilising experienced engineers supplemented by the guidance contained herein.

UPS equipment, particularly for signalling power supplies, shall be “product accepted” by Network Rail. New equipment being introduced onto Network Rail infrastructure should be put on trial first using the Zone Safety Review Group process. Safety documentation should be prepared, demonstrating how any imported risks will be mitigated and how the success criteria will be measured. The resulting documentation should be sufficient to fulfil the “product acceptance” process.

However, the product acceptance process does not guarantee the performance of each individual unit supplied therefore a testing regime based on elements included in section 5.16 should be introduced where required.

5 Technical Issues

5.1 Configuration

The recommended configurations for Distribution Network Operator (DNO), Diesel Generator and 25kV Overhead Line supplied power are shown in Appendix A. These configurations provide the most reliable, tried and tested arrangements for railway distribution systems. It should be noted that under normal and alternative supply operating conditions, the UPS must be connected to the load at all times. This ensures that the critical load is supplied with a regulated and filtered supply, to predetermined standards.

Traditional brick or concrete buildings are often ideal accommodation for electronic equipment as the internal temperature variation is minimal and very often additional heating and ventilation is not required.

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Where existing buildings are unavailable, experience to date indicates that UPS equipment that is pre-packaged within purpose built Relocatable Equipment Buildings (REBs) provides a cost effective, reliable and high quality installation solution, as opposed to applications where equipment is constructed at site. In addition, this method can assist suppliers in achieving the noise and environment requirements of [RT/E/PS/00007](#).

Installation of UPS and indeed any sensitive electronic equipment must not be considered within lightweight buildings such as GRP Kiosks.

All the possible modes of operation of the UPS within the distribution system must be examined, in order to ensure that the supply will be maintained as required. These include:

- Light Load
- Heavy Load
- Over Load
- System Fault
- Leading Power Factor Loads

Where a UPS is being installed within an existing system the unit must be capable of maintaining the existing signalling supply point busbar voltage.

In order to aid in the identification of those features of a UPS, which require assessment on a project by project basis, a data sheet (Appendix E) has been produced which highlights features described within [RT/E/PS/00007](#).

5.2 Rectifier

The rectifier exists to supply the inverter with electrical energy and charge the battery. Clearly the rectifier must be capable of supplying both the inverter and the battery at the same time after the battery has been discharged for a period. Excessive a.c. ripple on the d.c. current produced by the rectifier will reduce the life of the battery. Modern rectifiers should be capable of providing a d.c. current which is clean enough for all applications.

The rectifier may be enlarged in order to increase the rate of charge of the battery however care should be taken to balance this against the heat given off by the unit during the charging period. In certain instances it may be prudent to minimise the amount of heat being generated by the UPS due to environmental conditions.

For systems that have mixed inputs (e.g. 650V single-phase from OLE and 400V three-phase from the DNO) a possible solution is to provide a dual rectifier on the input of the UPS. A common d.c. busbar, which feeds the battery and inverter, may then be supplied from either source.

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The other attribute of the rectifier, which should be considered when purchasing a UPS, is its ability to draw current with low distortion from the supply as a distorted supply will affect both upstream wound components such as transformers and generators and also may reach limits set by the DNO (Electricity Association Document G5/4 Planning Levels for Harmonic Voltage Distortion). The greater the degree of harmonic current drawn by the rectifier, the higher the diesel generator rating will have to be in order to maintain the alternator winding temperatures within limits and provide an adequate supply. Rectifiers are generally supplied as either a six-pulse or a twelve-pulse unit. The higher the number of pulses (switching frequency) the lower the distortion seen on the input. Filters on the input to the rectifier can also be utilised to minimize the distortion.

The majority of modern industrial UPS equipments will draw current with very low distortion at unity power factor. Care should be taken when embedding UPS equipment into distribution systems known to have high levels of distortion and at that point the requirements of G5/4 and BS EN 61000-3-4 "Limitation of emission of harmonic currents etc." should be taken into account when specifying/purchasing equipment.

5.3 Inverter

The majority of the characteristics of an inverter are described in section 4 'Safety Considerations' and 5.7 'Fault levels'.

The speed at which the inverter operates and hence at which the waveform is synthesized will have a bearing on the ability of the UPS to recover from sudden changes in demand. With modern PWM UPS equipment the switching speed is usually more than adequate for typical Network Rail applications.

5.4 Standby Generators

In many installations, the standby supply is derived from a diesel generator. Network Rail has an asset base of over 300 generating sets that are used to support signalling supplies in the event of DNO supply failure.

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Where a UPS is being installed within a system that already includes a standby diesel generator, very careful consideration must be given to the interaction between the units. In order to correctly match the UPS and generator, the mechanical and electrical characteristics of the two machines, including AVR time constants, Governor time constants, Alternator Reactances, Alternator Time Constants, UPS gains etc. must all be addressed. However, when such a match is being performed, consideration must be given to the ageing and hence potential change in performance, which is why the time constants must be carefully selected through design, rather than just tweaked during commissioning. The expected load on the diesel engine must be selected so as to avoid the increased maintenance that is required as a result of low combustion chamber temperatures, carbon build-up and excessive wear that results from light loading.

For new installations of diesel generator and UPS equipment, the general rule of thumb for matching is to use a ratio of 1.6:1, whereby a UPS of 50kVA rating should be matched with a standby generator of at least 80kVA. This ratio may be reduced through detailed design of the UPS and generator package.

It is possible to install a UPS downstream of a diesel generator that has a lower kVA rating. However, in this circumstance, careful consideration must be given to the rating of the generator against the existing load, given the additional losses introduced by the UPS. It may be more practical to introduce the generator into the bypass leg of the UPS only, so as to avoid any possible conflict with ratings and time constants.

Other considerations, such as air-conditioning and older diesel generating sets, which provide an overload capability, should also be taken into account, when sizing the UPS. It should also be noted that both generator and UPS inverter will need to be oversized by up to as much as 200% for operation with a 3/1 phase Scott wound or open delta output transformer.

Where a diesel generator is supporting a UPS, the system should be arranged so that any minor disruptions to the mains supply do not result in the engine starting. It is recommended that the generator starting is delayed for at least one minute from mains failure in order to minimise the number of start requests made upon the generator.

5.5 Site Survey

Previous experience has proved that site surveys and monitoring of the existing supply at a potential UPS site is critical to the success of the design. Monitoring over a 24 hour period will demonstrate the variability of the supply over the peak and off-peak periods. Surveys will reveal limitations to the existing electrical distribution and physical access arrangements to the site. For systems employing transformers, the surveys will also indicate the nominal input/output voltage and tapping requirements. Where UPS equipment is to be installed in existing buildings, information can be gathered, which will assist in making the decision, as to the degree of environmental control required for the installation. Following monitoring of the system, characteristics such as load power factor may be established, in order to accurately size the UPS. Typical monitoring results are shown in **Fig.2**.

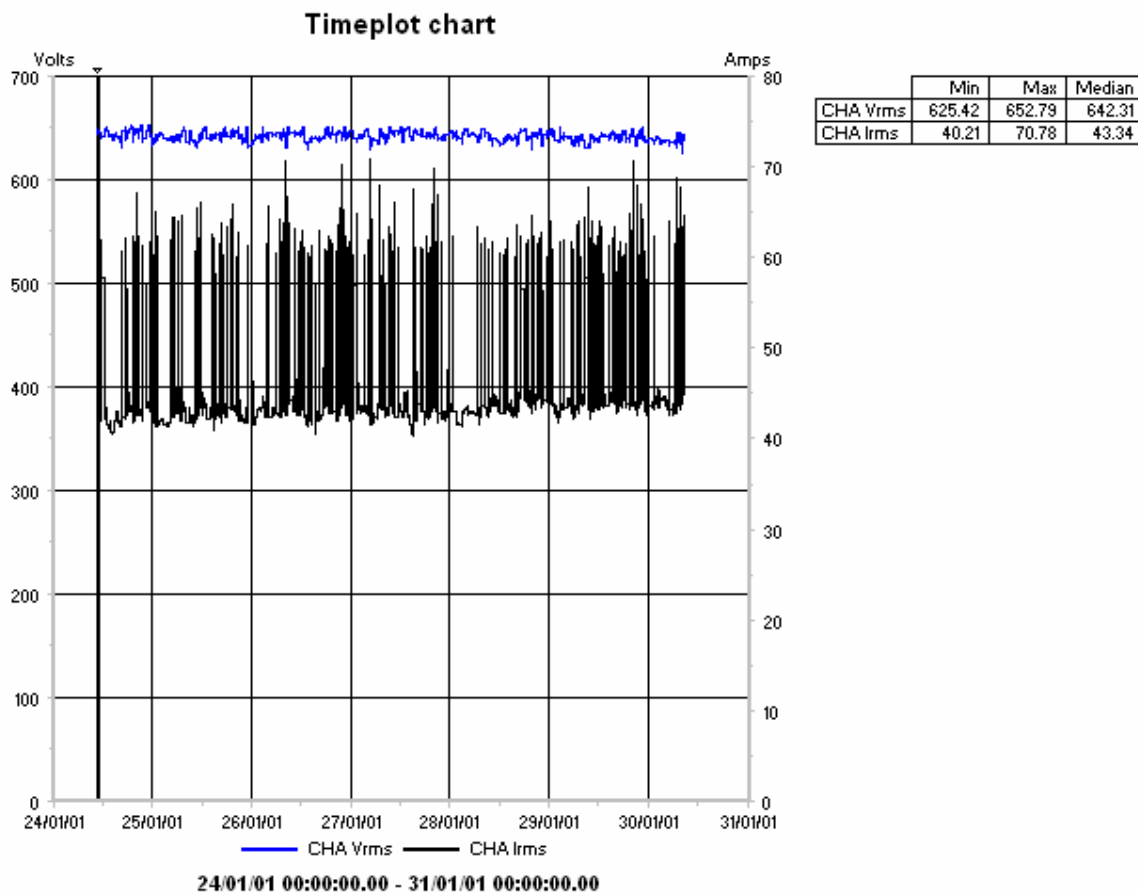


Figure 2

The plot above shows the supply voltage and current at a site across a seven day period. Large deviations in respect to the base load characteristics are indicated at certain times of the day.

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Whilst recording the average load at regular intervals it is advisable to record any 'events', that is to say substantial deviations from the standard voltage or current i.e. changes in excess of 15% for current or voltage and changes in excess of 1% in frequency. The capability of the monitoring equipment available will define how much of this information may be recorded. A detailed record of the characteristics of the load will enable a better solution to be provided by the UPS manufacturer.

Details of the level of harmonic pollution should be established and where possible the characteristics of the DNO supply investigated (Fault Capability, X/R Ratio etc.) in case the connection is weak and hence would require extra precautions in the design.

5.6 Power Rating and Efficiency

Most UPS systems are rated in both kVA (at a specified power factor) and kW. For example; UPS units may be specified as 10kVA at 0.8pf or 8kW. In this example, 8kW is the maximum power available at unity power factor. Therefore, a UPS unit at 12.5kVA at 0.8pf or 10kW should be specified, if 10kW is required at unity power factor.

Allowance for growth and short-term peak demands should also be considered. However, over sizing is both expensive and can increase operating costs. Most UPS systems operate at peak efficiency between 50% and 100% of their rating.

As the UPS is operating 24 hours per day and 365 days per annum, operating efficiency is an important consideration.

Manufacturers can specify the efficiency of UPS units in many ways and care should be taken to account for the criteria and configurations used. In all cases, these values will be affected by power factor and linearity of the load and ultimately the basis for consideration will be assessment of the whole life operating costs for the UPS.

5.7 Fault Levels

Inverter equipment has always appeared as a high impedance source to downstream equipment, due to the capabilities of the switching devices and the need to protect the inverter stack against high transient currents. As a result of this high source impedance, downstream protective devices need to be rated at a fraction of the UPS power rating. Very often, the UPS has to switch to the bypass supply, in order to provide sufficient energy for the downstream device to operate. Even using the bypass supply, the static switch will often have a current rating far beneath that of the incoming supply.

During the design of the UPS installation, the fault capability of the UPS must be clearly established. The addition of output transformers to a UPS will clearly reduce the level of fault current from the unit. The use of low impedance transformers may help. Fault levels throughout the system must be established during detailed design.