

Category 1 Standard

S1105 Power Service Contract - Performance Specification



**Please read the Written Notices
attached to this standard**

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MAYOR OF LONDON

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1 Purpose

- 1.1 The purpose of this Standard is to identify the requirements for equipment, systems and processes on the LU power system following the termination of the Power Service Contract on the 16th August 2013. Attached to this standard are all the key requirements retained from those within the Power Service Contract.

2 Scope

- 2.1 This Standard applies to equipment, systems and processes on the LU power system.

3 Requirements

- 3.1 The mandatory requirements of this standard are set out in the attachments to this document.
- 3.2 Where an attachment refers to the 'Contractor' it should be taken to mean LU and LU Suppliers following the termination of the Power Service Contract.
- 3.3 Where the attachment refers to the 'System' it should be taken to mean the LU power system including its associated SCADA system and the operational properties.

Note: The requirements contained in the attachments to this standard retain the structure and style used in the Power Service Contract. It is the intention to fully re-work this LU standard into the standards format over a period of time. Any queries regarding this standard should be brought to the attention of the LU technical authority.

4 Responsibilities

- 4.1 **The Head of Power Engineering** is responsible for the technical content of this standard. Any concessions in relation to this standard shall be directed to the Head of Power Engineering who has overall accountability for compliance with this standard. The Head of Power Engineering may request support from the other technical authorities when reviewing concessions or queries arising from the application of this standard.
- 4.2 **LU and LU Suppliers** shall be responsible for compliance with the requirements of this standard.
- 4.3 **Heads of Profession** are the LU technical authorities for each asset group, and shall be responsible for auditing technical compliance with this standard in accordance with the engineering asset grouping of LU Standard S1041 and with respect to the assurance of assets to which they are accountable for. They shall provide support to the Head of Power Engineering, if requested, with regard to any technical issues arising from concession requests or other queries to this standard.



5 Supporting information

5.1 Background

- 5.1.1 From the 16th August 1998 through to the 15th August 2013 the LU power system was operated, maintained, renewed and upgraded by UK Power Network Services (UKPNS) Powerlink under the Power Services Contract. The contract was a Private Finance Initiative contract where LU specified its requirements for equipment, systems and processes through the various contract clauses and schedules.
- 5.1.2 UK Power Network Services (UKPNS) have been working to the requirements of the Power Service Contract for the 15 year duration of the contract. When LU terminated the Power Service Contract on the 16th August 2013 it decided to retain the key requirements set out in the contract in this LU standard.

Note: At the time this standard was updated, it was deemed necessary to retain a non-standard for standard format. This however, does not diminish the mandatory requirements contained within the attachments.

5.2 Safety, Environment and Customer Considerations

- 5.2.1 Safety, environment and customer considerations relevant to this engineering standard are covered within the text of the attachment.

6 References

6.1 References and Abbreviations

- 6.1.1 Where references and abbreviations are used in this engineering standard they are given within the text of the attachment.

6.2 Definitions

- 6.2.1 Where definitions are used in this engineering standard they are given within the text of the attachment.
- 6.2.2 The following topic specific definitions are created:
- a) Within London Underground's Glossary of Terms (1-622)
(a Category 1 Standard);

Term	Definition	Source
LU	London Underground is the operating company of the former London Underground Limited.	a
Supplier	Supplier to London Underground, the primary organisation or individual that is selected to deliver a product, service or facility to London Underground and contracting directly to London Underground. This includes Consultants, Contractors, Infracos and PFI Contractors and excludes organisations or individuals selected by and contracting directly to them.	a



6.3 Person Accountable for the Document

Person accountable for the document
Phil Carmichael - Head of Power Engineering

6.4 Document History

Issue no	Date	Changes	Author
A1	October 2007	Standard 2-01303-001 re formatted and re-numbered to 1-105, no technical changes have been made to the content other than changing references to other Standards where their numbers have changed.	Clause 2.2.2.2 revised for COG
A2	April 2008	Clause 2.2.2.2 revised for COG and subsequent review by the Power Team	
A3	Dec 2011	Renumbered, reformatted and revised as per DRACCT 00339. Update of LU, BS and other Standard references.	Phil Carmichael
A4	August 2013	Updated to incorporate contract clauses for continuity following the termination of the Power Service Contract on the 16 th August 2013. Refer to DRACCT No. 01933.	Phil Carmichael



7 Attachment – Power Service Contract Performance Specification

POWER SERVICE CONTRACT SCHEDULE 5.1 PERFORMANCE SPECIFICATION PART 1



1 Delivery

- 1.1 The Contractor shall deliver Power of each of the forms specified in paragraph 2.1 (low voltage ac), 2.2 (dc) 2.3 (signalling), 2.4 (low voltage dc), 2.5 (DLR high voltage ac), 2.6 (Emergency Power) and 3 (compressed air) below to the Delivery Points appropriate for that form of Power at each Substation Switchroom and Transformer Room in Appendix 1 and Appendix 3.
- 1.2 To the extent that deviations from the obligations in paragraph 1.1 are attributable solely to the occurrence and disconnection of an electrical fault on the System, and providing the Electrical Protection provided in accordance with this Performance Specification ensures disconnection of the electrical fault within the minimum practicable time (and in any event no longer than 3 seconds, except in the case of pole to pole short circuit faults as stated in 2.2.5.3), the Contractor shall not for the duration of that electrical fault be in breach of paragraph 1.1 in relation to the affected Delivery Point. The Contractor shall not by virtue of this paragraph 1.2 be relieved of any liability or responsibility for damage to any property or equipment, or the consequences of any such damage.
- 1.3 The delivery requirements of this Schedule 5.1 shall be subject to Clause 6.

2 Electrical Parameters

2.1 Low voltage ac three phase and single phase Power

2.1.1 General

- 2.1.1.1 The Contractor shall comply with the requirements of paragraph 2.1 in relation to the delivery of Power taking the form of 400V, 50 Hz three phase and / or 230V, 50 Hz single phase supplies (low voltage ac Power) and the operation, maintenance and renewal of the System in relation to such Power.
- 2.1.1.2 For low voltage ac three phase and single phase supplies the Delivery Point shall be the boundary between the circuit side termination of the circuit breaker, fuse, combined fuse switch or isolator which forms part of the System and the outgoing cable forming part of LU's Distribution System. Without prejudice to the definition in Schedule 1.1, Figure 2.1 shows the Delivery Points in diagrammatic form.
- 2.1.1.3 Associated with each low voltage ac Delivery Point the Contractor shall make the following provision:
- i) where a circuit breaker exists at the Starting Date the Contractor shall make physical provision in the form of a circuit breaker to enable each such individual Delivery Point to be controlled as required for Interface Switching;
 - ii) where a circuit breaker does not exist at the Starting Date the Contractor shall make physical provision to enable the Delivery Point to be manually switched. The Contractor shall manually switch the supply associated with any such Delivery Point at the request of LU in accordance with the Technical Interface Procedures, Schedule 15.1(d).
- 2.1.1.4 Suitable physical and procedural means shall be provided for the Isolation of each low voltage ac Delivery Point in accordance with the Technical Interface Procedures, Schedule 15.1(d). The Contractor shall operate and administer a low voltage ac isolation procedure for the low voltage ac cable mains which form part of LU's Distribution System in accordance with the Rule Book and the Technical Interface Procedures, Schedule 15.1 (d).



2.1.2 Voltage

- 2.1.2.1 The nominal voltage at each Delivery Point shall be 400V measured between the phase conductors and 230V measured between the phase and neutral conductors.
- 2.1.2.2 The System shall be such that the voltage variation at the Delivery Point shall be between +10% to +2% of the nominal voltage except as permitted by paragraph 2.1.7. This provision shall not impose any obligation upon the Contractor to maintain continuous measurements of voltage levels.

2.1.3 Frequency

- 2.1.3.1 The frequency at each Delivery Point when the System is not inter-connected with any circuits governed by the Distribution Code or Grid Code shall be 50 Hz $\pm$ 2 Hz.
- 2.1.3.2 The frequency at each Delivery Point where the System is inter-connected with circuits governed by the Distribution Code or Grid Code will normally be 50 Hz $\pm$ 0.5 Hz, as regulated by those codes.

2.1.4 Fault Levels

- 2.1.4.1 The Contractor shall declare maximum and minimum fault levels, 12 months after the Starting Date, for every low voltage ac Delivery Point busbar on the system. These fault levels shall not be varied upward above the maximum, or downward below the minimum declared values, without approval by LU.
- 2.1.4.2 The Contractor shall not be liable for any failure of the equipment of LU or any Indirect User to withstand the fault levels in existence at the Starting Date prior to such declaration.
- 2.1.4.3 LU shall ensure that the equipment installed as part of the LU Distribution System or any Indirect User shall be of adequate rating to withstand the fault levels as declared by the Contractor.

2.1.5 System Earthing

- 2.1.5.1 All low voltage ac Power supplies shall be solidly earthed in accordance with a TN-S system as defined in BS 7671 and BS 7430. Substation and Transformer Room earthing shall be in accordance with paragraph 10.4.

2.1.6 Electrical Protection

The Contractor shall ensure that:

- 2.1.6.1 Electrical Protection on the System shall be such that it shall minimise within the technical limitations of the equipment provided injury and danger occurring as a result of faults and overloads on LU's Distribution System. Electrical Protection and settings shall be selected such that both the duration of fault current flows and consequent voltage disturbances shall be limited to the minimum practicable, consistent with maintaining discrimination further downstream.
- 2.1.6.2 Except as stated below, Electrical Protection on the System shall be such that any injury or danger that arises due to the disconnection of Power supplies shall be minimised. Hazards due to the disconnection of supply may be tolerated only where it is necessary to prevent a greater hazard arising as a result of the fault or overload. The Contractor shall ensure that spurious operations and incorrect discrimination in Electrical Protection are minimised.
- 2.1.6.3 Electrical Protection as described in paragraphs 2.1.6.4 and 2.1.6.5 and in accordance with BS 7671 shall be provided on the System to protect equipment forming part of LU's Distribution System.



- 2.1.6.4 Electrical Protection shall be provided on the System associated with each Delivery Point. This protection shall ensure that faults are disconnected within the minimum practicable time and overloads are prevented from causing damage to equipment forming part of LU's Distribution System, while supplies are continued to the loads connected to the Delivery Points which are not experiencing fault or overload conditions.
- 2.1.6.5 Electrical Protection on the System shall also be provided to ensure that disconnection of supplies under fault conditions is ensured in the event of a failure of the Electrical Protection provided in paragraph 2.1.6.4. This shall occur within the minimum practicable time, whilst still providing the maximum practicable discrimination.
- 2.1.6.6 When reasonably requested by the Contractor for the purposes of complying with the requirements of paragraph 2.1, LU shall provide the Contractor with relevant details of its Electrical Protection and those of any Indirect User. The Electrical Protection settings on the System shall be such as to provide co-ordination with LU's downstream protection scheme so far as reasonably practical. To allow LU to select appropriate Electrical Protection equipment and settings on the LU Distribution System, the Contractor shall provide relevant details of the Electrical Protection on the System, when reasonably requested by LU.
- 2.1.6.7 Changes made by the Contractor or LU to either the protection settings and / or maximum or minimum fault levels which affect the grading between Electrical Protection forming part of the System and LU's Distribution System will be subject to agreement by both Parties.

2.1.7 Electromagnetic Compatibility - Conducted

- 2.1.7.1 The standards known as IEC 61000-2-1, IEC 61000-2-4, and BS IEC 61000-2-6 shall be applied at the Delivery Points. Compatibility levels for harmonic voltage shall be taken from Class 3, IEC 61000-2-4. Compatibility levels for voltage changes and unbalance shall be taken from Class 2, IEC 61000-2-4.
- 2.1.7.2 The Contractor shall use the latest industry standard methods to take account of the effect of background distortion. Both the harmonic voltage amplitude and the angle shall be considered. IEC 61000 4-7 shall be applied when measuring harmonics.
- 2.1.7.3 Where the compatibility levels specified in paragraph 2.1.7.1 are not being met and there is no detrimental effect on either Party's equipment or systems, the Parties shall co-operate to determine suitable levels and standards of electromagnetic compatibility to ensure the proper and continued operation of the System and LU's Distribution System provided that this shall not excuse the Contractor from complying with any safety or environmental requirements in relation to electromagnetic compatibility.

2.2 DC Power

2.2.1 General

- 2.2.1.1 This section applies to all dc Power (whether traction or non-traction) except where only traction or non traction is specifically referred to. This Section does not apply to low voltage dc power, which is covered in Section 2.4.
- 2.2.1.2 For dc Power supplies the Delivery Point shall be the boundary between the circuit side termination of the circuit breaker, fuse, combined fuse switch or isolator which forms part of the System and the outgoing cable forming part of LU's Distribution System. Without prejudice to the definition in Schedule 1.1, Figure 2.1 shows in diagrammatic form the Delivery Points.



- 2.2.1.3 Associated with each dc Delivery Point the Contractor shall make physical provision in the form of both a positive circuit breaker and negative contactor to enable each individual Delivery Point and each dc busbar section to be controlled as required for Interface Switching.
- 2.2.1.4 Suitable physical and procedural means shall be provided for the Isolation of each dc Delivery Point in accordance with the Technical Interface Procedures, Schedule 15.1(d).
- 2.2.1.5 The Contractor shall maintain all dc busbar section breakers and contactors which exist at the Starting Date. Following renewal of a dc busbar the Contractor shall provide dc busbar section breakers to permit the electrical separation between:
- i) depot tracks and running line tracks;
 - ii) tracks of different Lines;
 - iii) tracks of the same Line connected to different Substations.

Without prejudice to paragraph 2.2.1.5, Figure 2.2 illustrates 2.2.1.5 iii) in diagrammatic form.

- 2.2.1.6 For the avoidance of doubt paragraph 2.2.1.5 does not require the contractor to fit additional transformer rectifiers as part of the renewal of a DC busbar where additional DC busbar section breakers are being provided in order to meet the requirements of paragraph 2.2.1.5. However, the Contractor shall ensure that sufficient space is provided should LU require the necessary additional transformer rectifiers subject to the space being available at no significant extra cost to the Contractor.
- 2.2.1.7 The Contractor shall comply with the requirements of paragraph 2.2 in relation to the delivery of dc Power, and the operation, maintenance and renewal of the System in relation to such Power.

2.2.2 Capacity and Voltage

- 2.2.2.1 The Contractor shall deliver dc Power to the extent that it is possible to do so without increasing the ratings of the equipment constituting the System. In this connection adjustments to the settings of equipment shall not constitute increases in rating. Changes to the following features of the Underground Network are the only changes which shall be deemed to necessitate changes to the ratings of the equipment constituting the System, from those prevailing at 1 January 1998:
- a) the time/current/speed relationship for trains;
 - b) train auxiliary loads;
 - c) timetabled train service;
 - d) conductor rail and LU's track feeder cable characteristics, line curvature, gradients and speed restrictions;
 - e) line signalling and control characteristics;
 - f) non traction dc loads;



- g) characteristics, length and impedance of the circuits to the lift and escalator distribution boards. Details of this information as on the dates of issue of each data schedule are listed in Appendix 6 The Contractor shall not be relieved from its responsibility for delivering dc Power by reason of paragraph 2.2.2.1 due to:
- i) changes of which LU had given the Contractor written notice before the Date of Contract; and/or
 - ii) changes attributable to any breach by the Contractor of its obligations under the Contract;
 - iii) subject to the provisions of Clause 23, changes in relation to which LU has issued a Variation Notice or Instruction Notice;
 - iv) changes which can be accommodated within the rating and ranges of the equipment as at 1 January 1998 and which LU notifies to the Contractor in sufficient time to permit any necessary change to the settings of equipment.

Paragraph 2.2.2.1 shall not prohibit the Contractor from increasing the ratings of equipment forming part of the System as part of the Contractor's routine renewal and or upgrade of equipment forming part of the System in line with Schedule 7.2.2 (Renewal and Upgrade Regime).



2.2.2.2 The minimum voltage at any train shall not be less than 450V. It is recognised that the Contractor is not responsible for the infrastructure between the Delivery Point and the shoe of the train. However the Contractor shall demonstrate compliance with the minimum train voltage requirement through design modelling, verified by appropriate train borne measurements. The modelling scenarios shall include localised geographical bunching of trains, resulting from a disruption to the normal timetable. The service disruption shall be modelled as defined in the following table:

Event order	Events	Simulation assumptions
1)	Normal Operation	Trains run according to the timetable and the limits of the signalling.
2)	First 3 Minutes of Perturbation	Trains continue to run as 'normally', but some will begin to stack up behind the train which is being held for 10 minutes, as limited only by the signalling.
3)	3 rd to 10 th minute of Perturbation	Trains continue to operate according to the timetable and signalling when running behind schedule, with the additional constraint that any train wishing to depart a platform, can only do so if it has a clear path into the next station's platform, limited to a maximum of 9 adjacent stations of the perturbation. This may be further approximated on very long inter-station distances.
4)	After Perturbation is Over	Trains run according to the limits of the signalling and minimum dwell/layover times.
	Further Guidance	Generally, a service perturbation will be simulated at every station unless a sample is agreed with London Underground to reduce modelling times. Trains should be prevented from leaving ahead of the scheduled departure time. Where there is the facility to switch services between fast and slow lines under perturbed conditions the following assumptions shall be made: • After 3 minutes the fast trains will be diverted to the slow lines where possible. • If at a "not timetabled to stop" station the trains will slow to 32kph at platform entry (front end of train at top of ramp at start of platform) and reaccelerate to line speed when the front of the train reaches the platform stop mark, unless the station is classified as an "all trains to stop" station, in which case the train will slow to 8km/hr before re-accelerating to the speed limit. Generally all section 12 stations are "all trains to stop". • Where a train has a choice of more than one platform at the next station ahead and station to station working is in place it should leave the station it is at if either platform at the next station is free and it should enter the free platform.



For the avoidance of doubt at the following locations the Contractor shall be obliged to comply with paragraph 2.2.2.2 for the purposes of modelling, in respect of the District and Bakerloo lines only at those sections of the Underground Network which are supplied with dc power fed from the System being:

District Line - Wimbledon Branch (dc track section 13)

Putney Bridge to Earls Court EB;
Earls Court to Putney Bridge WB;

District Line - Richmond Branch (dc track section 10)

Chiswick Park to Ravenscourt Park EB local;
Ravenscourt Park to Chiswick Park WB local;

Bakerloo Line (dc track section 7)

Kilburn Park to Queen's Park NB;
Queen's Park to Kilburn Park SB.

The following sections of railway are fed from Network Rail substations and the Contractor shall not be obliged to meet the requirements of paragraph 2.2.2.2 on any such section:

District Line - Wimbledon Branch

Putney Bridge to Wimbledon, down road, from the end of LU DC Section 13;
Wimbledon to Putney Bridge, up road, up to LU DC Section 13;

District Line - Richmond Branch

Chiswick Park to Richmond, down road, from the end of LU DC Section 10;
Richmond to Chiswick Park, up road, up to LU DC Section 10;

Bakerloo Line

Queen's Park to Harrow and Wealdstone, down road, from the end of LU DC Section 7;
Harrow and Wealdstone to Queen's Park, up road, up to LU DC Section 7;

Waterloo and City Line

Waterloo to Bank.



- 2.2.2.3 The nominal pole to pole voltage at each Delivery Point shall be 630V with the following exceptions:

Sub-station	Nominal pole-to-pole voltage
Loughton	710V
Epping	710V
Roding Valley	670V
Notting Hill Gate	630V (possibly rising to 710V)

- 2.2.2.4 When the rectifiers are loaded to less than 5% of rated direct current, the maximum output voltage of the rectifiers supplying each Delivery Point shall be 850V.

- 2.2.2.5 When the rectifiers are loaded to greater than 5% of rated direct current, the maximum output voltage of the rectifiers supplying each Delivery Point shall be 670V with the following exceptions:

Sub-station	Maximum output voltage
Loughton	750V
Epping	750V
Roding Valley	710V
Notting Hill Gate	670V (possibly rising to 750V)

- 2.2.2.6 Transient voltage excursions shall not be such as to cause interference with the correct operation of the rolling stock, signalling systems or communications equipment. Guidance concerning rolling stock transient voltage withstand capability may be obtained by reference to LU Standard G 6381.

- 2.2.2.7 The minimum voltage at any escalator and or lift distribution board shall be 450V.

2.2.3 Fault Levels

- 2.2.3.1 The Contractor shall ensure that the peak prospective fault current from the System at each Delivery Point shall not exceed 90 kA.

2.2.4 System Earthing

- 2.2.4.1 Where necessary for existing traction earth fault detection systems following the implementation of the Initial Works, Part 3 of Schedule 13.1, and where earthing resistors are located within a Substation at the Starting Date, the Contractor shall ensure that each pole of the dc supplies shall be earthed via resistors affixed to points on the System such that the positive pole to earth voltage is 2/3 of the nominal voltage and the negative pole to earth voltage is 1/3 of the nominal voltage.

- 2.2.4.2 As part of the implementation of the Initial Works, Part 3 of Schedule 13.1, or when a change is made to the earthing resistors, the Contractor shall ensure that the sensitivity of LU's voltage based traction earth fault detection system to earth fault, as it exists at the Starting Date, is maintained whilst retaining the overall stability of the earth fault detection system. The Contractor shall replace existing track-side resistors with resistors of same value, with a suitable tapping range to allow the values to be changed. The replacement resistors shall be within substations. The Contractor shall co-operate with LU in reviewing resistor values. In addition the values of the earthing resistors shall be subject to agreement with LU. For equipment installed subsequent to the Starting Date, including for the avoidance of doubt the Northern Line Initial Works, paragraph 2.2.5.5(b) shall supersede this requirement.



2.2.5 Electrical Protection

The Contractor shall ensure that:

2.2.5.1 Electrical Protection on the System shall be such that it shall minimise within the technical limitations of the equipment provided injury and danger occurring as a result of faults and overloads on LU's Distribution System.

2.2.5.2 Except as stated below Electrical Protection on the System shall be such that any injury or danger that arises due to the disconnection of Power supplies shall be minimised. Hazards due to the disconnection of supply may be tolerated only where it is necessary to prevent a greater hazard arising as a result of the fault or overload. The Contractor shall ensure that spurious operations and incorrect discrimination in Electrical Protection are minimised.

2.2.5.3 Pole-to-pole short circuit Electrical Protection shall be provided on the System at the dc Delivery Points to disconnect LU's Distribution System in the event of a pole-to-pole short circuit on LU's Distribution System. The following requirements shall be met:

- a) to the extent in existence at the Starting Date or to the extent the relevant equipment is renewed, protection systems in accordance with class H or V of BS EN 50123-1 shall be provided at all dc Delivery Points. All dc Delivery Points shall be protected by devices with direct acting, high speed, fault current limiting characteristics;
- b) secondary protection shall be provided at all traction dc Delivery Points to supplement the protection in paragraph 2.2.5.3 (a) where it cannot be set to detect all pole to pole short circuits while permitting operation of a full train service in accordance with (a) to (e) of paragraph 2.2.2.1 or the operation of non traction loads in accordance with (f) and (g) of paragraph 2.2.2.1. Further requirements for this protection are given in paragraph 2.2.5.4;
- c) fault duration's shall be minimised within the technical limitations of the equipment provided and in no case shall the disconnection time exceed 60 seconds. The let through I^2t shall not exceed $1.22 \times 10^9 \text{ A}^2\text{s}$ where I = current in Amperes and t = time in seconds;
- d) full account shall be taken of the nature of the loads to be supplied and of any special circumstances such as the use of Regenerative Braking of trains, lifts or escalators. The Electrical Protection shall not mal-operate due to the presence of dc ripple. Particular attention shall be given by the Contractor to ensuring correct co-ordination and discrimination between the Electrical Protection on the System and the Electrical Protection on the Underground Network;

Note: Should it become apparent that full compliance with paragraph 2.2.5.3 (d) is not possible, due to the technical limitations of the equipment which the Contractor is providing, the Contractor will be required to apply for a concession. Agreement of this concession by LU will not be unreasonably withheld.

- e) the Electrical Protection shall not limit the ability of the System or LU's Distribution System to deliver power up to its Installed Capacity (or in the case of LU's Distribution System its full capacity) except where necessary to prevent injury or danger or damage to equipment;
- f) the Electrical Protection and settings shall ensure correct discrimination so far as reasonably practical;
- g) in so far as is reasonably practicable the rectifier protection shall be set to provide back-up protection in the event of dc track feeder protection failure or a dc track feeder circuit breaker which has failed to operate.



2.2.5.4 Secondary Electrical Protection:

The secondary Electrical Protection referred to in paragraph 2.2.5.3 b) shall meet the following requirements:

- a) the Electrical Protection shall operate for all pole-to-pole faults as far as reasonably practical. This shall include all current and/or voltage conditions which are not the result of the operation of the train service in accordance with (a) to (e) of paragraph 2.2.2.1 or non traction loads in accordance with (f) & (g) of paragraph 2.2.2.1;
- b) detection and clearance of faults shall be achieved within the minimum practicable time consistent with the basis of detection applicable. The maximum permissible time between the occurrence of the out of limit condition and the operation of Electrical Protection shall not be greater than 300 ms except in the case of:
 - i) timed overcurrent trip protections in place at the Starting Date, in which case settings compliant with paragraph 2.2.5.3 c), shall be acceptable;
 - ii) under voltage protection, in which case the maximum permissible time between the occurrence of the out of limit condition and the operation of the Electrical Protection shall be the minimum practicable time but not be greater than 2s.
- c) where under voltage protection is used in order to comply with the requirements set out in 2.2.5.3 b), it shall be arranged such that tripping does not occur when the high voltage supplies are lost to a Site:

For the avoidance of doubt, the under voltage protection mentioned in paragraph 2.2.5.4 c) relates to that provided as part of an inter-tripping scheme which provides secondary Electrical Protection as required under paragraph 2.2.5.3 b). It does not refer to the under voltage protection fitted to the transformer rectifier circuits as required by paragraph 2.2.5.6.
- d) the Electrical Protection shall operate under minimum fault conditions while remaining stable under maximum load or through fault conditions as far as reasonably practical. The Electrical Protection shall distinguish between a fault and a load. In the case of Traction Power it shall operate only for faults within the Traction Current Section (as defined in the Rule Book) which it is designed to protect;
- e) where systems are in place at the Starting Date and for all new systems the Electrical Protection shall initiate an alarm, but not cause a trip, via the SCADA System in the event of loss of current or voltage signal or in the event of loss of the Power supply to the Electrical Protection or loss of any inter-trip system associated with the Electrical Protection system:

Guidance concerning the selection and setting of this protection may be obtained by reference to LU Standard G-111.



2.2.5.5 Earth faults

- a) The Earth Fault detection within Substations which gives alarm and analogue indications of a pole-earth fault at the Main Power Control Centre shall be maintained until it is superseded either on completion of the Initial Works, Part 1 of Schedule 13.1 or by other works. The Contractor shall ensure that the unbalanced current protection systems, in place at the Starting Date, shall be maintained until such time as they are superseded. In all cases the Contractor shall ensure that earth fault annunciation shall be available at all locations where Interface Switching can be carried out.
- b) LU standard 1-117 shall be met for all new traction earth fault detection systems under paragraph (a) (excluding the works implemented as part of the Initial Works, Part 3 of Schedule 13.1).

2.2.5.6 Rectifier Loss of Supply Protection

Electrical Protection shall be provided on the System such that the transformer rectifiers will be disconnected automatically when the high voltage supply to these circuits fails. The high voltage supply shall be deemed to have failed if the voltage falls below 60% of nominal for a period of two seconds or longer.

2.2.5.7 Protection Co-ordination

Changes made by the Contractor or LU to either the existing protection settings and / or maximum or minimum fault levels which affect the grading between Electrical Protection forming part of the System and LU's Distribution System will be subject to agreement by both parties.

2.2.6 Electromagnetic Compatibility - Conducted

- 2.2.6.1 Electrical distortion such as ripple, present in the dc Power shall not be such as to cause interference with the operation of trains, signalling, communications or other equipment.
- 2.2.6.2 In respect of new equipment, the Contractor shall apply the latest BS EN 60146-1-1, 60146-1-3 and BS EN 50328 and 50329 or equivalent IEC for the electrical interference when converting ac to dc. In respect of equipment existing at the Starting Date the Contractor shall apply the British Standard relevant at the date of equipment manufacture for the electrical interference when converting ac to dc.
- 2.2.6.3 Neither the Contractor nor LU shall vary their electrical systems, traction type or associated equipment in a manner which may significantly alter the electrical distortion of the dc Power without having first consulted and gained the consent of the other Party. Reference should be made to the work of IEC Technical Committee No. 77 and its sub committees.

2.2.7 DC Traction Conductor Rail Resistance Measurements

- 2.2.7.1 The Contractor shall undertake loop resistance measurements of the conductor rail of each dc current rail section as described in paragraph 2.2.7.2. The resistance measurements shall be undertaken on a five yearly basis and the results of the measurements submitted to LU within four weeks of the completion of each individual test.

A dc current rail section is the length of track which interconnects two adjacent substations.



2.2.7.2 Measurement Method

Before carrying out any conductor rail loop resistance measurements it will be necessary to ensure the following:

- a) all possible sources of dc traction voltage are switched off and isolated;
- b) all measurements shall be carried out in line with the LU Rule Book .

The conductor rail loop resistance measurement shall be carried out to a minimum accuracy of +/- 5% of the resistance calculated.

A pole to pole short circuit of a known resistance shall be applied within the substation at one end of the dc current rail section.

At a substation low voltage dc source shall be applied to the other end of the dc current rail section between each of the poles. The voltage source shall have a constant voltage characteristic.

The current and source voltage measurements shall be carried out with the following nominal currents flowing; 90, 95, 100, 105 and 110 A. Each measurement shall be made once the steady state value of the circulating current has been reached.

The resistance of the dc current rail section conductor rail loop shall be calculated by dividing the source voltage by the current which flows in the loop.

The final loop resistance shall be the average of the five resistance measurements carried out minus the resistance of the applied short circuit and the test leads used in the test circuit.

Once the loop resistance measurement is complete it shall be checked using a micro-ohm meter to carry out a direct resistance measurement.

For single end fed sections, the short will be applied to the track, the voltage being applied at the substation.

2.2.7.3 Measurement Results

As part of each individual test the following information shall be recorded:

- a) site person in charge;
- b) date;
- c) location/description of dc current rail section (taken from LU's Rule Book);
- d) direction of train travel;
- e) weather conditions (for surface current rail sections only);
- f) substation at which short circuit applied or location of track short circuit;
- g) substation at which source voltage is applied;
- h) description of each item of equipment used, including as a minimum:
 - i) type;
 - ii) manufacturer;
 - iii) serial No; and
 - iv) calibration certificate details.



- j) the following shall be recorded for each set of measurements taken:
 - i) source voltage (volts);
 - ii) current (amps);
 - iii) resistance calculated (milliohms); and
 - iv) ambient temperature (degrees Celsius).
- k) milliohm meter;
- l) resistance of applied short circuit (milliohms);
- m) resistance of test leads (milliohms); and
- n) dc current rail section loop resistance value (milliohms).

2.2.8 Bonding of Running Rail Earth and Substation Earth

No connection shall be made between the substation earthing system and any running rail without the express approval of LU.

2.3 Signalling Equipment Power

2.3.1 General

- 2.3.1.1 The Contractor shall comply with the following requirements in relation to the delivery of Power for signalling equipment supplies and the operation maintenance and renewal of the System in relation to such Power. 400V, 50 Hz three phase signalling equipment supplies shall be in accordance with paragraph 2.1.
- 2.3.1.2 For signalling equipment supplies the Delivery Point shall be the boundary between the circuit side termination of the circuit breaker, fuse, combined fuse switch or isolator which forms part of the System and the outgoing cable forming part of LU's Distribution System. Without prejudice to the definition in Schedule 1.1, Figure 2.1 shows the Delivery Points in diagrammatic form.
- 2.3.1.3 Associated with each signalling equipment supply Delivery Point the Contractor shall make physical provision in the form of a circuit breaker or a contactor with an overload device to enable each individual Delivery Point to be controlled as required for Interface Switching. Such provision shall be by way of maintenance of relevant equipment existing at the Starting Date and renewal of that equipment in accordance with the Renewal and Upgrading Regime and by provision, maintenance and renewal of equipment where none exists as at the Starting Date, when associated equipment at those Delivery Points is renewed or upgraded.
- 2.3.1.4 Suitable physical and procedural means shall be provided for the Isolation of each signalling equipment Delivery Point in accordance with the Technical Interface Procedures, Schedule 15.1(d). The Contractor shall operate and administer a signalling low voltage ac isolation procedure for the signalling low voltage ac cable mains which form part of LU's Distribution System in accordance with the Rule Book and the Technical Interface Procedures, Schedule 15.1 (d).



2.3.1.5 The capacity required at each signalling equipment Power Delivery Point is dependent on the configuration of the Signal Supply System. The Contractor shall:

- i) subject to paragraph 2.3.1.5 (ii) supply to LU the signalling equipment Power required to meet the amount of signalling Power which LU determines it requires to run the Underground Network;
- ii) not be obliged to supply more signalling equipment Power than the System is capable of supplying at the Starting Date;
- iii) subject to paragraph 2.3.1.5 (ii) ensure that at all times sufficient Capacity is available at each site listed in Appendix 1.3, in order to supply the amount of signalling equipment Power which LU determines it requires to run the Underground Network, as notified through the Annual Loading Plan;
- iv) subject to paragraph 2.3.1.5(ii) take all reasonable efforts to ensure that the System is, when required by LU, capable of delivering signalling equipment Power up to the Installed Capacity at each Delivery Point. For the avoidance of doubt, the Contractor shall not be deemed to be acting unreasonably solely by virtue of complying with its obligations under the Operation and Maintenance Regime and the Renewal and Upgrading Regime. The Contractor shall notify LU as soon as reasonably practicable in advance when the Installed Capacity will not be available (such notification providing the reasons why the Installed Capacity will not be fully available).

2.3.2 Voltage

2.3.2.1 The nominal voltages measured between conductors at each Delivery Point shall be as defined in Appendix 1.3.

2.3.2.2 The levels of voltage variation at the Delivery Point supplied from a frequency changer shall be between +6% to -5% of the nominal voltage and supplied from a signal transformer shall be between +10% to +2% of the nominal voltage.

2.3.3 Frequency

2.3.3.1 For 125 Hz signalling equipment Power the frequency at each Delivery Point shall be 125 Hz +3 Hz / -8 Hz.

2.3.3.2 For 33.33 Hz signalling equipment Power the frequency at each Delivery Point shall be 33.33 Hz + 1.66 Hz / - 3.33 Hz.

2.3.3.3 For 50 Hz signalling equipment, the frequency at each Delivery Point where the System is not interconnected with circuits governed by the Distribution Code or Grid Code shall be 50 Hz $\pm$ 2 Hz. Where the System is inter-connected with circuits governed by the Distribution Code or Grid Code, the frequency at the Delivery Points will normally be 50 Hz $\pm$ 0.5 Hz as regulated by those codes.

2.3.3.4 Signalling equipment Power on the Victoria Line shall be disconnected automatically if the frequency at the Delivery Points associated with the Victoria Line falls below 119 Hz.

2.3.4 Fault Levels

Both parties will cooperate to ensure that fault levels at busbars associated with Signalling Equipment are managed within levels that will ensure correct operation of the Protection Equipment.



The Contractor and LU will act jointly to maintain compatibility between Signalling Equipment and fault levels thus continuing safe and secure operation and avoid damage to the Signalling Equipment.

It is recognised that at some sites the minimum fault level will be too low for correct operation of current driven Protection Equipment. In such cases the Contractor shall ensure that the Signalling Equipment will be protected by the under-voltage protection described in Paragraph 2.3.5.6 (ii).

2.3.5 Electrical Protection

The Contractor shall ensure that:

- 2.3.5.1 Electrical Protection on the System shall be such that it shall minimise within the technical limitations of the equipment provided injury and danger occurring as a result of faults and overloads on LU's Distribution System;
- 2.3.5.2 Except as stated below Electrical Protection on the System shall be such that any injury or danger that arises due to the disconnection of Power supplies shall be minimised. Hazards due to the disconnection of supply may be tolerated only where it is necessary to prevent a greater hazard arising as a result of the fault or overload. The Contractor shall ensure that spurious operations and incorrect discrimination in Electrical Protection are minimised.
- 2.3.5.3 Electrical Protection as described in paragraphs 2.3.5.4 to 2.3.5.8 inclusive shall be provided at the Delivery Points to protect equipment forming part of LU's Distribution System against overload or short circuit.
- 2.3.5.4 Electrical Protection shall be provided in the form of overcurrent protection at the Delivery Points to ensure that faults are disconnected within the minimum practicable time and overloads are prevented from causing damage while supplies are continued to the loads connected to the Delivery Points which are not under fault or overload condition.
- 2.3.5.5 Electrical Protection shall also be provided to ensure that disconnection of supplies under fault conditions is ensured in the event of a failure of the protection provided in paragraph 2.3.5.4. This shall occur within the minimum practicable time, whilst still providing the maximum practicable discrimination.
- 2.3.5.6 Subject to paragraph 2.3.5.7:
 - i) supplies to the Delivery Points shall be disconnected immediately should the voltage at the Delivery Point exceed the nominal voltage plus 16%; and
 - ii) supplies to the Delivery Points shall be disconnected should the voltage at the Delivery Point fall below the nominal voltage minus 12% for 600V systems and the nominal voltage minus 61% for 440V systems for 3 seconds.
- 2.3.5.7 The Contractor shall not be in breach of paragraph 2.3.5.6 where equipment in place at the Starting Date does not conform with paragraph 2.3.5.6. The Contractor shall ensure that wherever any relevant equipment is replaced or renewed it shall conform to paragraph 2.3.5.6.
- 2.3.5.8 Earth fault detection with the ability to detect any fault between either of the two conductors and ground shall be provided on all single phase signalling equipment supplies as required pursuant to Part 4 of the Initial Works. This earth fault detection system shall, subject to the provisions of Schedule 13.1 Part 4, enable the location of single earth faults, specific to an individual cable connected between two substations.



- 2.3.5.9 When reasonably requested by the Contractor for the purposes of complying with the requirements of paragraph 2.3, LU shall provide the Contractor with relevant details of its Electrical Protection and those of any Indirect User. The Electrical Protection settings on the System shall be such as to provide co-ordination with LU's downstream protection scheme as far as reasonably practical.

To allow LU to select appropriate Electrical Protection equipment and settings on the LU Distribution System, the Contractor shall provide relevant details of the Electrical Protection on the System, when reasonably requested by LU.

- 2.3.5.10 Changes made by the Contractor or LU to the protection settings, and/or maximum or minimum fault levels which affect the grading between Electrical Protection forming part of the System and LU's Distribution System will be subject to agreement by both Parties.

2.3.6 System Earthing

The 600V supplies and the 440V supplies shall operate without a deliberate connection between earth and either conductor in accordance with an IT (Isolée Terre) system as defined in BS 7671; apart from any connections which may be necessary under paragraph 2.3.5.8 which shall be of a high impedance. The supply arrangements shall be such that neither conductor to earth voltage can exceed the limits set out in paragraph 2.3.2 for voltages between conductors.

2.3.7 Electromagnetic Compatibility - Conducted

No change shall be made to the equipment forming the System or the part of the Signal Supply System which forms part of LU's Distribution System which could cause a change to the harmonic voltage and / or current distortion within the Signal Supply System without prior agreement between the Parties. The Parties shall co-operate to determine suitable levels and standards of electromagnetic compatibility to ensure the proper and continued operation of the System and the Signal Supply System provided that this shall not excuse the Contractor from complying with any safety or environmental requirements in relation to electromagnetic compatibility.

2.4 Low voltage dc Power

2.4.1 General

- 2.4.1.1 The Contractor shall comply with the requirements of paragraph 2.4 in relation to the delivery of Power taking the form of 50V, 100V and 110V dc (low voltage dc power) and the operation, maintenance and renewal of the System in relation to such Power.
- 2.4.1.2 For low voltage dc supplies the Delivery Point shall be the boundary between the circuit side termination of the circuit breaker, fuse, or isolator which forms part of the System and the outgoing cable forming part of LU's Distribution System.
- 2.4.1.3 Associated with each low voltage dc Power Delivery Point the Contractor shall make physical provision to enable the Delivery Point to be manually switched. The Contractor shall manually switch the supply associated with any such Delivery Point at the request of LU in accordance with the Technical Interface Procedures, Schedule 15.1(d).
- 2.4.1.4 Suitable physical and procedural means shall be provided for the Isolation of each low voltage dc Power Delivery Point in accordance with the Technical Interface Procedures, Schedule 15.1(d). Where relevant equipment is not in existence as at the Starting Date for this purpose the Contractor shall provide the necessary physical means when associated equipment at the Delivery Point is renewed or upgraded.



2.4.2 Voltage

- 2.4.2.1 The nominal voltage at each Delivery Point shall be either 50 V, 100V or 110V measured between the supply conductors.
- 2.4.2.2 The System shall be such that the voltage variation at the Delivery Points shall be between -10% to +30% of the nominal voltage.

2.4.3 Fault Levels

The Contractor shall ensure that rated fault levels of equipment forming part of LU's Distribution System are not exceeded.

The Contractor shall declare maximum and minimum fault levels, 12 months after the Starting Date, for every low voltage dc Delivery Point busbar on the System. These fault levels shall not be varied upward above the maximum, or downward below the minimum declared values, without approval by LU.

The Contractor shall not be liable for any failure of the equipment of LU or any Indirect User to withstand the fault levels in existence at the Starting Date prior to such declaration.

LU shall ensure that the equipment installed as part of LU's Distribution System or any Indirect User shall be of adequate rating to withstand the fault levels as declared by the Contractor.

2.4.4 System Earthing

The low voltage 50V, 100V and 110V dc supplies shall operate without a deliberate connection between earth and either supply conductor in accordance with an IT (Isolée Terre) system as defined in BS 7671, apart from any connections which may be necessary under paragraph 2.4.5.4 which shall be of a high impedance. The supply arrangements shall be such that neither conductor to earth voltage can exceed the limits set out in paragraph 2.4.2 for voltages between conductors.

2.4.5 Electrical Protection

The Contractor shall ensure that:

- 2.4.5.1 Electrical Protection on the System shall be such that it shall minimise within the technical limitation of the equipment provided injury and danger occurring as a result of faults and overloads on LU's Distribution System. Electrical Protection equipment and settings shall be selected such that both the duration and magnitude of fault current flows and consequent voltage disturbances shall be limited to the minimum practicable, consistent with maintaining discrimination further downstream.
- 2.4.5.2 Except as stated below, Electrical Protection on the System shall be such that any injury or danger that arises due to the disconnection of Power supplies shall be minimised. Hazards due to the disconnection of supply may be tolerated only where it is necessary to prevent a greater hazard arising as a result of the fault or overload. The Contractor shall ensure that spurious operations and incorrect discrimination in Electrical Protection are minimised.
- 2.4.5.3 Electrical Protection shall be provided on the System associated with each Delivery Point. This protection shall ensure that faults are disconnected within the minimum practicable time and overloads are prevented from causing damage to equipment forming part of LU's Distribution System, while supplies are continued to the loads connected to the Delivery Points which are not experiencing fault or overload conditions.



- 2.4.5.4 Earth fault detection with the ability to detect any fault between either of the two conductors and ground shall be provided on all low voltage dc supplies.

The Contractor shall not be liable for any failure of the equipment of LU or any Indirect User to withstand the fault levels in existence as at the Starting Date until replaced or renewed.

- 2.4.5.5 When reasonably requested by the Contractor for the purposes of complying with the requirements of paragraph 2.4, LU shall provide the Contractor with relevant details of its Electrical Protection and those of any Indirect User. The Electrical Protection settings on the System shall be such as to provide co-ordination with LU's downstream protection scheme, as far as reasonably practicable.

To allow LU to select appropriate Electrical Protection equipment and settings on the LU Distribution System, the Contractor shall provide relevant details of the Electrical Protection on the System, when reasonably requested by LU.

- 2.4.5.6 Changes made by the Contractor or LU to either the protection and / or maximum or minimum fault levels which affect the grading between Electrical Protection forming part of the System and LU's Distribution System will be subject to agreement by both Parties.

2.4.6 Electromagnetic Compatibility - Conducted

The ripple content of low voltage dc supplies shall not exceed 50 mV flat, 5 mV root-mean-square above 3 kHz and shall not be less than 2 mV CCITT (International Telegraph and Telephone Consultative Committee).

2.5 Docklands Light Railway High Voltage ac Power

2.5.1 General

- 2.5.1.1 The Contractor shall comply with the requirements of paragraph 2.5 in relation to the delivery of high voltage ac Power taking the form of 11 kV, 50 Hz three phase supplies to the Docklands Light Railway (DLR) system. The responsibilities for the operation, maintenance and renewal of the System in relation to such Power are given in the Electricity Operation and Maintenance Agreement between LU and DLR "The DLR O&M Agreement". For the purpose of this Contract the Contractor shall act as an agent of LU in as much that the Contractor will meet LU's obligations to DLR as set out in the DLR O&M Agreement.

LU will consult and agree with the Contractor any changes to the DLR O&M Agreement which would increase the Contractor's obligations. In addition the Contractor will be entitled to charge for any work carried out pursuant to any "Call out obligations" set out in the Schedule to the DLR O&M Agreement at the rates given therein or such other rates as may be agreed.

- 2.5.1.2 For high voltage ac supplies to DLR the Delivery Point shall be the boundary between the circuit side termination of the circuit breaker or isolator which forms part of the System and the outgoing cable. The ownership, operating access and maintenance are as defined in the DLR O&M Agreement.
- 2.5.1.3 Associated with each high voltage ac Delivery Point to DLR the Contractor shall make physical provision in the form of a circuit breaker to enable each such individual Delivery Point to be remotely controlled. The Contractor shall operate the circuit breaker associated with each such Delivery Point at the request of LU or DLR in accordance with the DLR O&M Agreement.
- 2.5.1.4 Suitable physical and procedural means shall be provided for the Isolation of each high voltage ac Delivery Point to DLR in accordance with the DLR O&M Agreement.



2.5.2 Voltage

- 2.5.2.1 The nominal voltage at each Delivery Point shall be 11 kV measured between the phase conductors.
- 2.5.2.2 The System shall be such that the voltage variation at the Delivery Points shall not exceed -6% to +6% of the nominal voltage.

2.5.3 Frequency

- 2.5.3.1 The frequency at each Delivery Point when the System is not inter-connected with any circuits governed by the Distribution Code or Grid Code shall be 50 Hz $\pm$ 2 Hz.
- 2.5.3.2 The frequency at each Delivery Point when the System is inter-connected with circuits governed by the Distribution Code or Grid Code will normally be 50 Hz $\pm$ 0.5 Hz, as regulated by those codes.

2.5.4 Fault Levels

The Contractor shall declare maximum and minimum fault levels, 12 months after the Starting Date, for the high voltage ac Delivery Point to DLR. The high voltage ac Delivery Points to DLR are defined in paragraph 2.5.1.2. The fault levels will be declared at the cable side of the termination on the DLR switchgear. These fault levels shall not be varied upward above the maximum, or downward below the minimum declared values, without approval by LU or DLR. The Contractor shall not be liable for any failure of the equipment of LU or any Indirect User to withstand the fault levels in existence at the Starting Date prior to such declaration.

2.5.5 System Earthing

- 2.5.5.1 The 11 kV high voltage ac Power supply to DLR shall be reactively earthed such that the maximum earth fault current which flows under earth fault conditions is 2.1 kA.
- 2.5.5.2 Substation and Transformer Room earthing shall be in accordance with paragraph 10.4.

2.5.6 Electrical Protection

The Contractor shall ensure that:

- 2.5.6.1 Electrical Protection on the System shall be such that it shall minimise within the technical limitations of the equipment injury and danger occurring as a result of faults and overloads on the DLR system. Electrical Protection equipment and settings shall be selected such that both the duration and magnitude of fault current flows and consequent voltage disturbances shall be limited to the minimum practicable, consistent with maintaining discrimination further downstream.
- 2.5.6.2 Except as stated below, Electrical Protection on the System shall be such that any injury or danger that arises due to the disconnection of Power supplies shall be minimised. Hazards due to the disconnection of supply may be tolerated only where it is necessary to prevent a greater hazard arising as a result of the fault or overload. The Contractor shall ensure that spurious operations and incorrect discrimination in Electrical Protection are minimised.
- 2.5.6.3 Electrical Protection as described in paragraphs 2.5.6.4 and 2.5.6.5 shall be provided on the System to protect equipment forming part of DLR's Distribution System against overloads and short circuits.



- 2.5.6.4 Electrical Protection shall be provided on the System associated with each Delivery Point. This protection shall ensure that faults are disconnected within the minimum practicable time and with the minimum number of circuits or plant items being disconnected in addition to the faulty item and overloads are prevented from causing damage to equipment forming part of the DLR system, while supplies are continued to the loads connected to the Delivery Points which are not experiencing fault or overload conditions.
- 2.5.6.5 Electrical Protection on the System shall also be provided to ensure that disconnection of supplies under fault conditions is ensured in the event of a failure of the Electrical Protection provided in paragraph 2.5.6.4. This shall occur within the minimum practicable time, whilst still providing the maximum practicable discrimination.
- 2.5.6.6 When reasonably requested by the Contractor for the purposes of complying with the requirements of paragraph 2.5, LU shall use reasonable endeavours to provide the Contractor with relevant details of DLR's Electrical Protection. The Electrical Protection settings on the System shall be such as to provide co-ordination, as far as reasonably practicable, with the downstream protection scheme of LU and/or any Direct User.
- To allow LU and DLR to select appropriate Electrical Protection equipment and settings on the LU Distribution System or on DLR's system, the Contractor shall provide relevant details of the Electrical Protection on the System, when reasonably requested by LU or DLR.
- 2.5.6.7 Changes made by the Contractor, LU or DLR to either the protection settings or maximum or minimum fault levels which affect the grading between Electrical Protection forming part of the System and the downstream protection will be subject to agreement by all parties.

2.5.7 Electromagnetic Compatibility - Conducted

- 2.5.7.1 The Contractor shall apply to all high voltage ac Delivery Points to DLR, all relevant Engineering Recommendations cited in the Distribution Code.
- 2.5.7.2 The Contractor shall use the latest industry standard methods to take account of the effect of background distortion. Both the harmonic voltage amplitude and the angle shall be considered. IEC 61000 4-7 shall be applied when measuring harmonics.
- 2.5.7.3 Where the compatibility levels specified in paragraph 2.5.7.1 are not being met and there is no detrimental effect on any party's equipment or systems the parties shall co-operate to determine suitable levels and standards of electromagnetic compatibility to ensure the proper and continued operation of the System and LU's Distribution System or DLR's distribution system provided that this shall not excuse the Contractor from complying with any safety or environmental requirements in relation to electromagnetic compatibility.

2.6 Emergency Power

2.6.1 General

- 2.6.1.1 The requirements of paragraph 2.6 apply at all times when the Contractor is providing Emergency Power. When required by the failure of normal supplies (as defined in paragraph 5.2). Emergency Power taking the form of 400V, 50 Hz three phase and / or 230V, 50 Hz single phase supplies (low voltage ac Emergency Power) shall be provided. The requirement to provide Local Emergency Power Supply Systems and the refurbishment of the Central Emergency Power Supply System is described in Schedule 9.1. The operation, maintenance and renewal of the Emergency Power Supply System shall be as described in the Regimes.



2.6.1.2 For low voltage ac Emergency Power supplies the Delivery Point shall be the boundary between the circuit side termination of the isolator which forms part of the Emergency Power Supply System and the outgoing cable forming part of LU's Station Electrical Distribution System. Without prejudice to the definitions in Schedule 1.1, Figure 2.3 shows the Delivery Point in diagrammatic form.

2.6.1.3 The Contractor shall make provision at each low voltage ac Emergency Power Delivery Point for the Delivery Point to be manually switched (bypassing the Local Emergency Power Supply Systems). The Contractor shall manually switch the supply associated with any such Delivery Point at the request of LU in accordance with the Technical Interface Procedures, Schedule 15.1(d).

2.6.1.4 Suitable physical and procedural means shall be provided for the Isolation of each low voltage ac Emergency.

Power Delivery Point in accordance with the Technical Interface Procedures, Schedule 15.1(d).

2.6.2 Capacity and Voltage

2.6.2.1 The nominal voltage at each low voltage ac Emergency Power Delivery Point shall be 400V measured between the phase conductors and 230V measured between the phase and neutral conductors as appropriate. The shape of the supply voltage at each Delivery Point shall be sinusoidal.

2.6.2.2 At any time when Emergency Power is being provided, the equipment used to provide low voltage ac Emergency Power shall be controlled such that the voltage variation at the Delivery Points shall not exceed +3% to -3% of nominal voltage, when the load is varied between 0 and 100%.

2.6.2.3 For each low voltage ac Emergency Power Delivery Point the Contractor shall provide details of any restrictions on the characteristics of loads which may be connected within LU's Station Electrical Distribution System which is fed from the relevant Delivery Point. The Defined Capacity of each low voltage ac Emergency Power Delivery Point shall be the total Installed Capacity at each Delivery Point.

2.6.2.4 As part of the implementation of the Emergency Supply Plan, the Contractor shall provide a schedule detailing the following information regarding each low voltage ac Emergency Power Delivery Point:

- a) Connected load (kW);
- b) Capacity of Local Emergency Power Supply System (kVA); and
- c) Spare capacity of Local Emergency Power Supply System at time of survey (%).

2.6.3 Frequency

The frequency at each low voltage ac Emergency Power Delivery Point shall be 50 Hz +/- 0.1 Hz, when supplied from the Local Emergency Power Supply System and 50 Hz +/- 2 Hz when supplied from the Central Emergency Power Supply System.

2.6.4 Fault Levels

2.6.4.1 The Contractor shall demonstrate as part of the Emergency Supply Plan that the rated fault levels of equipment forming part of LU's Station Electrical Distribution System are not exceeded.

LU will advise the Contractor of the maximum fault levels pertaining to existing installations.



- 2.6.4.2 The Contractor shall declare maximum/minimum fault levels for each Local Emergency Power Supply System as part of the handover documentation. The Contractor shall not be liable for any failure of the equipment of LU or any Indirect User to withstand fault levels in existence at the Starting Date prior to such declaration.
- 2.6.4.3 The short circuit capability of the Local Emergency Power Supply System shall be such that all down stream Electrical Protection devices operate effectively under all reasonably foreseeable conditions without causing damage to the equipment providing the supply. The Contractor shall demonstrate as part of the Emergency Supply Plan that the protective devices forming part of the Emergency Power Supply System operate correctly when supplied from all power sources i.e. the REC supply, local battery systems and central generation.
- 2.6.4.4 The Contractor shall declare maximum/minimum fault levels for the Central Emergency Power Supply System 3 months after the Starting Date.
- The Contractor shall not be liable for any failure of the equipment of LU or any Indirect User to withstand fault levels in existence at the Start Date prior to such declaration.
- 2.6.4.5 The short circuit capability of the Central Emergency Power Supply System shall be such that all down stream Electrical Protection devices operate effectively under all reasonably foreseeable conditions without causing damage to the equipment providing the supply. The Contractor shall demonstrate as part of the Emergency Supply Plan that the protective devices forming part of the Emergency Power Supply System operate correctly when supplied from all power sources.

2.6.5 System Earthing

All low voltage ac Emergency Power supplies shall be solidly earthed in accordance with a TN-S system as defined in BS 7671 and BS 7430.

2.6.6 Electrical Protection

The Contractor shall ensure that:

- 2.6.6.1 Electrical Protection on the Emergency Power Supply System shall be such that it shall minimise within the technical limitation of the equipment provided injury and danger occurring as a result of faults and overloads on LU's Distribution System. Electrical Protection settings shall be selected such that both the duration and fault current flows and consequent voltage disturbances shall be limited to the minimum practicable, consistent with maintaining discrimination.
- 2.6.6.2 Except as stated below, Electrical Protection on the System shall be such that no injury or danger shall arise due to the disconnection of Power supplies. Hazards due to the disconnection of supply may be tolerated only where it is necessary to prevent a greater hazard arising as a result of the fault or overload. The Contractor shall ensure that spurious operations and incorrect discrimination in Electrical Protection are minimised.
- 2.6.6.3 Electrical Protection shall be provided on the Emergency Power Supply System to protect equipment forming part of LU's Distribution System against all faults in accordance with BS 7671.
- 2.6.6.4 The Electrical Protection associated with each Delivery Point shall ensure that faults are disconnected within the minimum practicable time and overloads are prevented from causing damage to equipment on LU's Distribution System, while supplies are continued to the loads connected to the Delivery Points which are not experiencing fault or overload conditions.



- 2.6.6.5 The Electrical Protection settings and any fuses used shall be such as to provide co-ordination with LU's downstream and upstream protection scheme. Changes made by the Contractor or LU to either the existing protection settings and/or maximum or minimum fault levels which affect the grading between Electrical Protection forming part of the Emergency Power Supply System and LU's Distribution System shall be subject to agreement.

2.6.7 Electromagnetic Compatibility - Conducted

- 2.6.7.1 The Contractor shall ensure electromagnetic compatibility for conducted signals between the Emergency Power Supply System and LU's Distribution System.
- 2.6.7.2 The harmonic distortion of the low voltage ac Emergency Power supplies shall not exceed 3% for linear loads, with no single harmonic exceeding 3% of the fundamental and 10% for non-linear loads.
- 2.6.7.3 Where the compatibility levels are not being met and there is no detrimental effect on either Party's equipment or systems the Parties shall co-operate to determine suitable levels and standards of electromagnetic compatibility to ensure compatibility and the proper and continued operation of the Emergency Power Supply System and LU's Distribution System provided that this shall not excuse the Contractor from complying with any safety or environmental requirements in relation to electromagnetic compatibility.

2.7 Bulk Supply Point (BSP) Switchhouse Static Var Compensator and Harmonic Filtering Unit Capacities

Bulk Supply Point (BSP) and Switchhouse Capacities

- 2.7.1 For each Contract Year, within six periods of receipt of the Annual Loading Plans, the Contractor shall provide the following information:
- 2.7.1.1 The Contractor shall identify the necessary installed and firm capacities at Bulk Supply Points and Switchhouses to meet System Demand and the demand of Indirect Users and/or to provide DLR with the power supplies contracted for the requirements of the Underground Network as identified in the Annual Loading Plan and the requirements of normal and degraded modes of operation identified in Contingency Plans in line with the requirements of paragraph 5 of the Performance Specification.
- 2.7.1.2 The Contractor shall advise LU of what Firm Service and Conditional Service Capacities are to be set in the Connection Agreements for each of the Bulk Supply Points to meet the requirements of paragraph 2.7.1.1.
- LU shall be responsible for ensuring that the Firm Service and Conditional Service Capacities set in the Connection Agreements for each Bulk Supply Point result in a near optimum technical and financial arrangement. However, the Contractor shall provide any technical assistance regarding the planning and load estimation on the System, required to enable LU to optimise the Firm Service and Conditional Service Capacities set in the Connection Agreements for each Bulk Supply Point.
- 2.7.2 The above information shall cover each Contract Year up to five years ahead and shall be of the highest accuracy possible, consistent with the quality of information contained in the Annual Load Plan.
- 2.7.2.A Any information outside of that required by paragraphs 2.7.1 and 2.7.2 shall be provided in accordance with clauses 5.6 to 5.8 and Schedule 5.10.
- 2.7.3 The methods used to comply with paragraphs 2.7.1 & 2.7.2 shall be in line with Schedules 7.2.1, 7.2.2, the Operation and Maintenance Regime and the Upgrade and Renewals Regime.



2.7.4 The Capacities of the Bulk Supply Points (BSP) and Switchhouses can be found within Appendix 1.7 of Part 2 of this Performance Specification.

2.7.5 *Static VAr Compensator and Harmonic Filter Equipment Capacity, Availability and Theoretical Reliability.*

2.7.5.1 For each Contract Year, within six Periods of receipt of the Annual Loading Plans, the Contractor shall indicate to LU whether changes or additions are needed to the Power Quality Compensation Equipment on the System. Unless otherwise agreed in writing, this indication will be based upon realistic and worst case scenarios for both harmonics and voltage fluctuations at each BSP. The scenarios shall allow comparison with the original base case design study. If extra work or services are required by LU to this, the cost of such extra work or services will be chargeable to LU and the basis upon which such work or services will be provided and the cost of such extra work or services will be agreed at the time.

2.7.5.2 The information provided pursuant to paragraph 2.7.5.1 of this Schedule shall cover long, medium and short term periods. The accuracy of this information shall be consistent with the quality of information contained in the Annual Loading Plan. Where the Contractor considers that the information provided by LU as part of the Annual Loading Plan is inadequate, the Contractor shall request further information from LU. LU shall provide such reasonably requested information as soon as is reasonably practicable. The Contractor shall be held harmless by LU for failing to comply with its obligations in paragraph 2.7.5.1 to the extent such failure is due to the failure by LU to provide adequate information.

2.7.5.3 [Not in use]

2.7.5.4 Actual Performance Requirements

Subject to paragraph 5.3 of the Schedule 7.2.2 the Contractor shall ensure that static VAR compensation and harmonic filtering shall be available at the BSPs for not less than the following percentages of time.

BSP	SVC% availability	i.e. SVC failure hours/ year	HF% availability	i.e. HF failure hours / year
Lots Road	99.9999	0.0011	99.9995	0.0407
Mansell St	99.9999	0.0011	99.9999	0.0011
Neasden	99.9797	1.9566	99.9997	0.0237
West Ham	99.9975	0.2204	99.9998	0.0170
Note: The third and fifth columns of the above table shall take precedence over the second and fourth columns to the extent of any inconsistency when calculating availability.				

The Harmonic Filter availability in the table above shall be measured as a moving total over seven years (seven by thirteen Periods), calculated as follows:

$$N\% = \frac{(\text{hours when Harmonic Filter compensation is available})}{8760 \times 7} \times 100$$

The SVC availability in the table above shall be measured as a moving total over thirteen years (thirteen by thirteen Periods), calculated as follows:

$$N\% = \frac{(\text{hours when SVC compensation is available})}{8760 \times 13} \times 100$$

The percentage availability figures will be reported every Period through inclusion in the four-weekly report. For reporting purposes, equipment is assumed to be 100% available up until the Completion Date for Phase 1 or the Completion Date for Phase 2 (as appropriate).

2.7.5.5 [Not in use]

2.7.5.6 To perform its obligations under paragraphs 2.7.5.1 to 2.7.5.3 the Contractor shall comply with Schedules 7.2.1, 7.2.2, the Operation and Maintenance Regime and the Upgrade and Renewals Regime.

2.7.5.7 The table contained in Appendix 1.10 sets out the capacities of the Static VAR Compensators and Harmonic Filters on the System. Any change to the capacities of the Static VAR Compensators or Harmonic Filters as set out in Appendix 1.10 shall be the subject of a further Variation in accordance with Clause 23.

2.8 LU's Verification of Contractor's Compliance for paragraphs 2.1 to 2.7

2.8.1 General

LU's verification of the Contractor's compliance with paragraphs 2.1, 2.2, 2.3, 2.4, 2.5, 2.6 and 2.7 shall be by review, audit and/or inspection undertaken in accordance with Schedule 43.3.



2.8.2 Capacity, Voltage and Frequency

LU's verification of the Contractor's compliance with paragraphs 2.1.2, 2.1.3, 2.2.2, 2.3.2, 2.3.3, 2.4.2, 2.5.2, 2.5.3, 2.6.2 and 2.6.3 shall be by audit of SCADA records and by witness and/or audit, of measurements undertaken by the Contractor at LU's request utilising portable measuring and recording instruments provided under the Initial Works, Part 7 of Schedule 13.1. In respect of traction dc delivery measurements shall be facilitated by LU and undertaken by the Contractor on board a train which is in serviceable condition and operating under service conditions, the connections being made as close as practicable to the collector shoes.

2.8.3 Fault Levels

LU's verification of the Contractor's compliance with paragraphs 2.1.4, 2.2.3, 2.3.4, 2.4.3, 2.5.4 and 2.6.4 shall be by audit of the Contractors calculations.

2.8.4 System Earthing

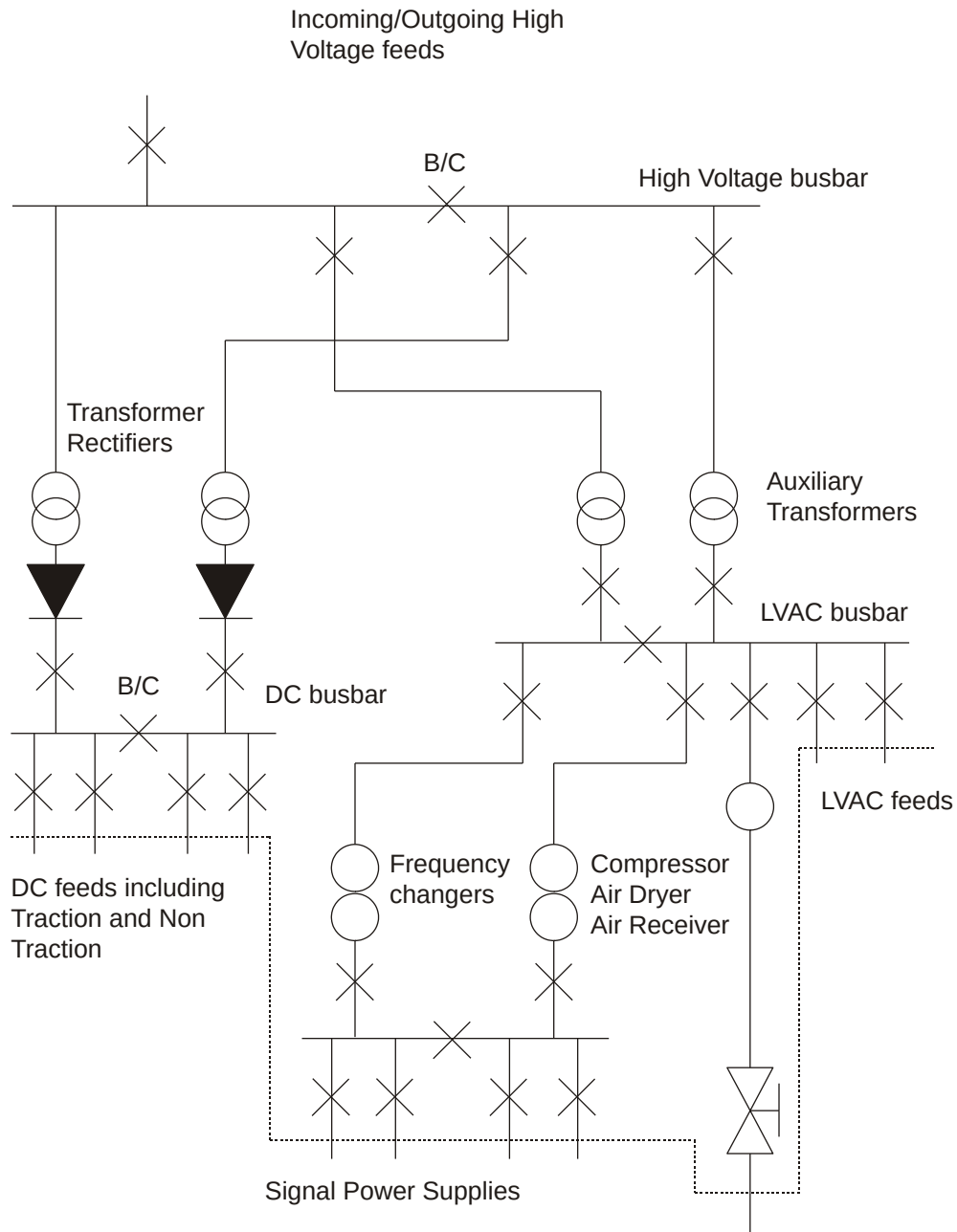
LU's verification of the Contractor's compliance with paragraphs 2.1.5, 2.2.4, 2.3.6, 2.4.4, 2.5.5 and 2.6.5 shall be by review, audit or inspection undertaken in accordance with Schedule 43.3 and by review and/or audit of the Contractors earthing calculations and measurements which shall have been made in accordance with BS 7430.

2.8.5 Electrical Protection

LU's verification of the Contractor's compliance with paragraphs 2.1.6, 2.2.5, 2.3.5, 2.4.5, 2.5.6 and 2.6.6 shall be by review audit and/or inspection of the Contractors commissioning, maintenance testing results, and Electrical Protection grading calculations.

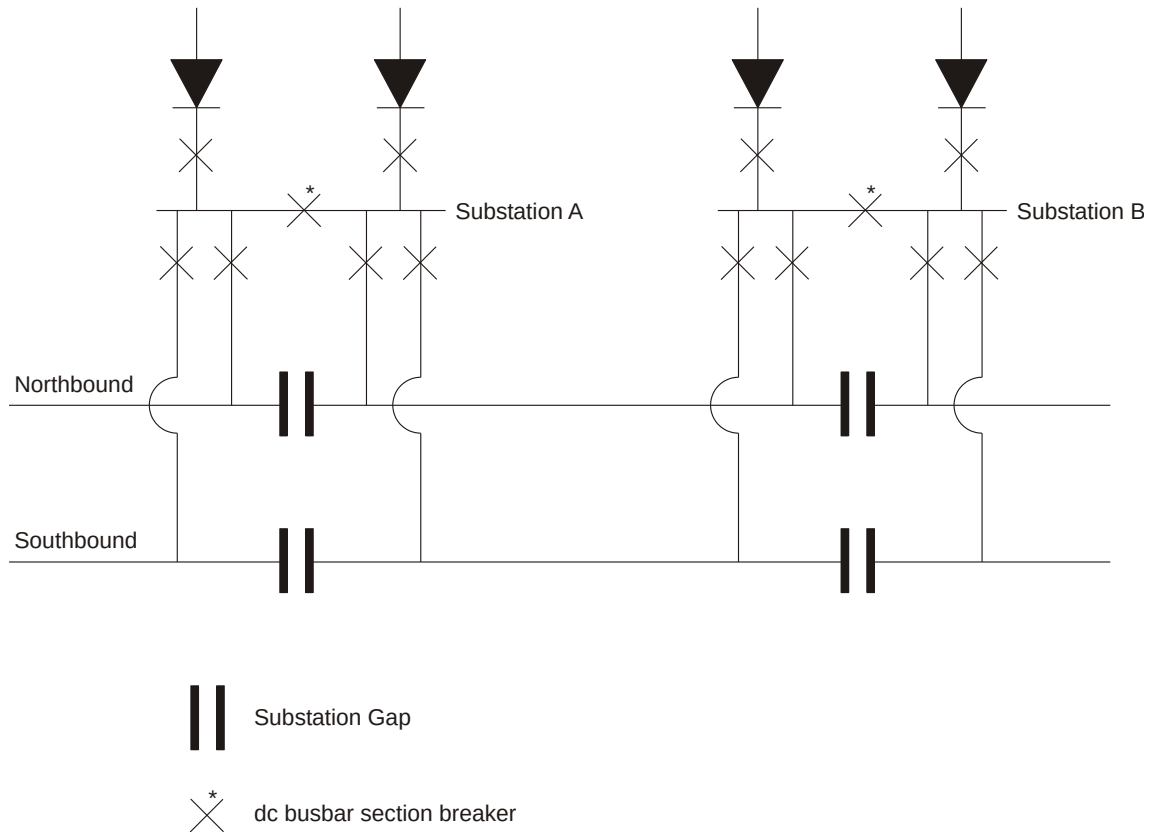
2.8.6 Electromagnetic Compatibility - Conducted

LU's verification of the Contractor's compliance with paragraphs 2.1.7, 2.2.6, 2.3.7, 2.4.6, 2.5.7 and 2.6.7 shall be by review, inspection and/or audit, of measurements undertaken by the Contractor in accordance with the Standards as specified in paragraphs 2.1.7, 2.2.6, 2.3.7, 2.4.6 and 2.5.7 and the requirements of 2.6.7 as relevant and by audit of the Contractors calculations.



Delivery Points are shown with dotted line

Figure 2.1 - Typical Substation Arrangement Showing Delivery Points



Busbar section breakers to permit separation between tracks of the same Line connected to different Substations.

Figure 2.2 - Illustration of 2.2.1.5 c)

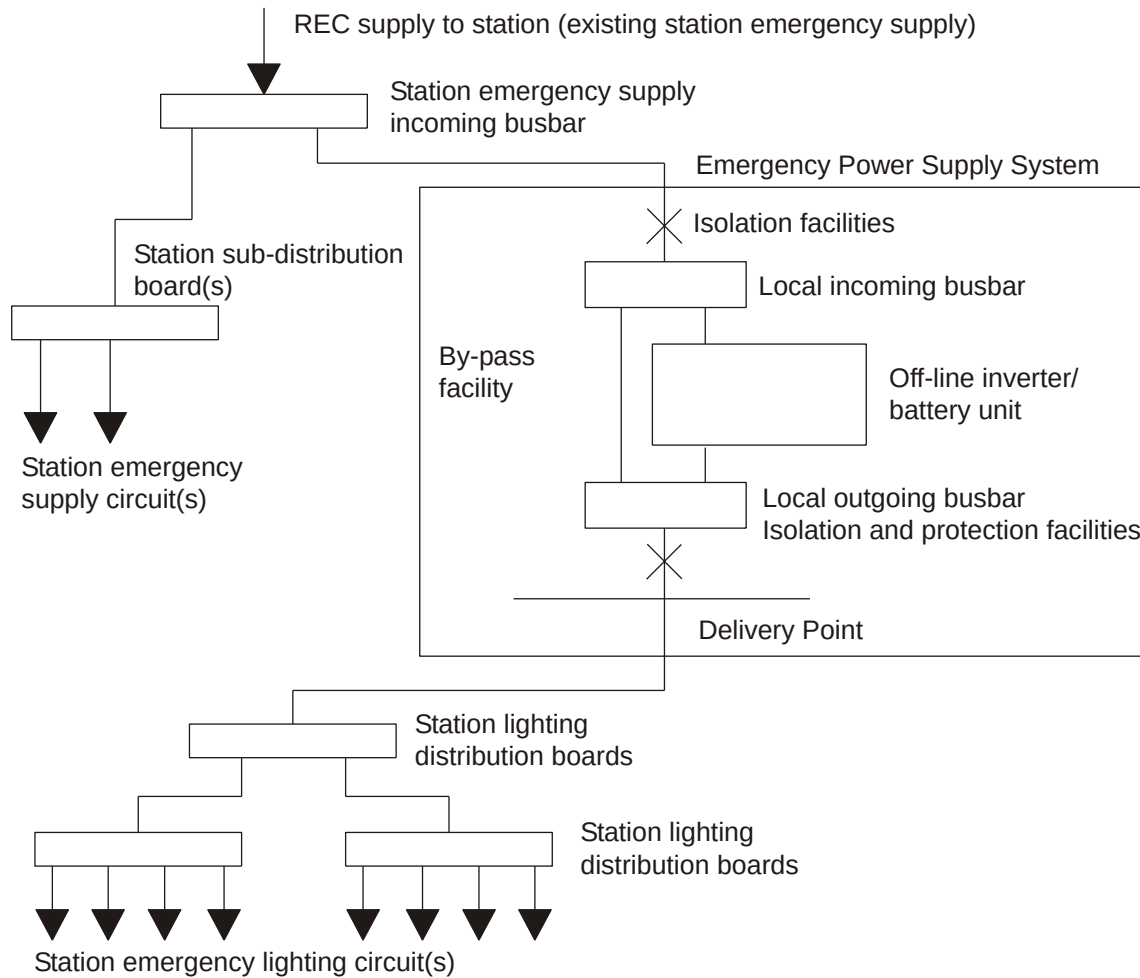


Figure 2.3 - Typical Emergency Power Supply Arrangement Showing Delivery Point and Emergency Power Supply System



3 Compressed Air Parameters and Tolerance

3.1 General

- 3.1.1 The Contractor shall supply compressed air of the quality set out in paragraph 3.2 and which shall be such as to permit LU to meet its obligations under the Pressure Vessels and Transportable Gas Containers Regulations 1989, HSE No 2169. The appropriate written schemes of inspection governing the use of pressure vessels in existence at the Starting Date shall be transferred to the Contractor.
- 3.1.2 For compressed air supplies the Delivery Point shall be the boundary between the downstream side of the final isolating cock forming part of the System and the outgoing pipe work forming part of LU's Distribution System. Without prejudice to the definition in Schedule 1.1, Figure 2.1 shows in diagrammatic form the Delivery Points.
- 3.1.3 Associated with each compressed air Delivery Point the Contractor shall make physical provision to enable each individual Delivery Point to be controlled as required for Interface Switching. Suitable physical and procedural means shall be provided for the Isolation of each compressed air Delivery Point in accordance with the Technical Interface Procedures, Schedule 15.1(d).
- 3.1.4 The capacity required at each compressed air Delivery Point is dependent on the configuration of the compressed air system. The Contractor shall:
- i) subject to paragraph 3.1.4 (ii) supply to LU the compressed air required to meet the amount of compressed air which LU determines it requires to run the Underground Network;
 - ii) not be obliged to supply a greater volume of compressed air than the System is capable of supplying at the Starting Date;
 - iii) subject to paragraph 3.1.4 (ii) ensure that at all times sufficient capacity is available at each site listed in Appendix 1.4, in order to supply the amount of compressed air which LU determines it requires to run the Underground Network;
 - iv) subject to paragraph 3.1.4 (ii) ensure that the Firm Service Capacities at operational sites as set out in Appendix 1.4 are available at all times; and
 - v) subject to paragraph 3.1.4 (ii) take all reasonable efforts to ensure that the System is, when required by LU, capable of delivering compressed air up to the Installed Capacity at each Delivery Point. For the avoidance of doubt, the Contractor shall not be deemed to be acting unreasonably solely by virtue of complying with its obligations under the Operation and Maintenance Regime and the Renewal and Upgrading Regime. The Contractor shall notify LU as soon as reasonably practicable in advance when the Installed Capacity will not be available (such notification providing the reasons why the Installed Capacity will not be fully available).
- 3.1.5 It can be assumed that the total number of air compressors will be reduced by 35% over the 30 years of the Power Service Contract. This reduction to be phased linearly through the Power Service Contract life.
- 3.1.6 As compressors become life expired the Contractor shall fit modular plug-in compressors at all operational sites. Exceptions to this may be agreed with LU in cases where plug-in modular compressors are impractical.



3.2 Compressed Air Quality

3.2.1 Particle Matter

- 3.2.1.1 The maximum particle size within the compressed air at the Delivery Point shall be no greater than 5µm.
- 3.2.1.2 The maximum concentration of solid contaminants within the compressed air at the Delivery Point shall be no greater than 5 mg/m³.

3.2.2 Water

- 3.2.2.1 At the maximum pressure the dew point shall occur at a temperature no higher than -20°C measured at Delivery Points supplying compressed air to sub-surface or surface areas of the Underground Network.
- 3.2.2.2 At the maximum pressure the dew point shall occur at a temperature no higher than +7°C measured at Delivery Points supplying compressed air to tube areas in the Underground Network except in tube areas of the Underground Network where the requirement at the Starting Date was - 20°C.

NOTE: In cases where lines are partly in tube and partly in sub-surface or surface areas of the network the most onerous requirements of -20°C applied at the Starting Date.

- 3.2.2.3 The applicable standard under paragraph 3.2.2 at the Starting Date for each Delivery Point is indicated in Appendix 1.4.

3.2.3 Oil

The maximum oil content within the compressed air at the Delivery Point shall be no greater than 25 mg/m³.

3.3 Compressed Air Pressure

- 3.3.1 The compressed air shall be supplied at the Delivery Point at a pressure of 3.2 barg minimum and 4.7 barg maximum.
- 3.3.2 Means shall be provided by the Contractor to ensure that compressed air is not supplied at the Delivery Point at a pressure in excess of 4.7 barg.
- 3.3.3 The Contractor shall ensure that the System shall be capable of providing compressed air into LU's Distribution System when LU's Distribution System is at atmospheric pressure.

For the avoidance of doubt paragraph 3.3.3 does not require the System to be capable of providing compressed air at a minimum pressure of 3.2 barg and a maximum pressure of 4.7 barg, whilst LU's Distribution System is at atmospheric pressure, but rather that the System is capable of providing compressed air into LU's Distribution System and raising its pressure to 3.2 barg, when it is at atmospheric pressure with normal loads attached, without any damage being caused to the System.

3.4 Earthing

The Contractor shall connect the compressed air equipment forming part of LU's Distribution System within any Substation to earth in accordance with BS 7430 and BS 7671.



3.5 LU's Verification of Contractor's Compliance

- 3.5.1 LU's verification of the Contractor's compliance with paragraph 3.1 shall be by review, audit and/or inspection undertaken in accordance with Schedule 43.3 by LU or their nominated representative.
- 3.5.2 LU's verification of the Contractor's compliance with paragraph 3.2 shall be by review, audit and/or inspection undertaken in accordance with Schedule 43.3 of the Contractor's measurements of the air quality. Where relevant this shall be at the Delivery Point or if this is not possible, the nearest convenient location to the Substation or if this is not possible by reference to the manufacturer's type test reports.
- 3.5.3 LU's verification of compliance with paragraph 3.3.1 shall be by review, audit and/or inspection undertaken in accordance with Schedule 43.3 of SCADA records.
- 3.5.4 LU's verification of compliance with paragraph 3.3.2 shall be by review, audit and/or inspection undertaken in accordance with Schedule 43.3 of the Contractor's installations, the written schemes of examination required under the Pressure Vessels and Transportable Gas Containers Regulations 1989, HSE No 2169 and the examination reports under those regulations.
- 3.5.5 LU's verification of compliance with paragraph 3.4 shall be by review, audit and/or inspection undertaken in accordance with Schedule 43.3 of the Contractor's earthing system. The inspection and test shall be carried out by the Contractor in accordance with BS 7430.

4 Security of Supply

4.1 Actual Performance

The Contractor shall ensure that:

- 4.1.1 Electricity shall be available and shall meet all the requirements of paragraph 2 at all times except:
- a) in accordance with a schedule of outages agreed in advance between the Contractor and LU as part of the Operation and Maintenance Regime or the Renewal and Upgrading Regime and during the Initial Works and complying with the Technical Interface Procedures, Schedule 15.1 (d);
 - b) during Engineering Hours in the case of dc traction supplies to line clear and line safe sections (as defined in the Rule Book) where supplies may cease to be available at the prior request of the Contractor. The Contractor should note that LU shall be entitled to suspend Engineering Hours without any notice, in which case the Contractor shall ensure that dc traction Power is provided in accordance with paragraph 2, subject to the restoration time necessary to comply with safety and Technical Interface Procedures, Schedule 15.1(d).
- 4.1.2 Compressed air at the Delivery Points shall not be less than 3.2 barg and not greater than 4.7 barg.
- 4.1.3 The ability of the Contractor to maintain pressure in accordance with paragraph 4.1.2 is dependent on the extent to which relevant pipework within LU's Distribution System leaks. The Parties shall agree any reasonably convenient test method to determine whether any breach of paragraph 4.1.2 is caused or contributed to by the condition of such pipework.



- 4.1.4 In the event that cleaning work/decontamination in the Blackwall Tunnel is not carried out by the authorities when required, consequent delays will be covered by the issue of a Variation, or, if agreed and it is appropriate, an extension of time under clause 13A, and/or a concession against affected performance. In the event that existing or future routes through the Blackwall Tunnel are not available, the consequence to the Contractor will be covered by a Variation.
- 4.1.5 Actual repair/restore times for each equipment category in Table A2.1.1 (not fixed for the Contract duration), as determined by the actual average repair time for that year, shall not exceed those repair/restore times given in Table A2.1.1 by more than 30% in any particular year, except that in every fifth year (review evenly staggered across the equipment categories in the five year period) the Actual repair/restore times for each equipment category in Table A2.1.1 (not fixed for the Contract duration), as determined by the average of the last 10 years of repair/restore time data included in the Annual Report in accordance with Schedule 43.3, shall not exceed those repair/restore times given in Table A2.1.1.

4.2 Theoretical Performance

- 4.2.1 The Contractor shall ensure that the arrangements in place to meet the obligations under this Contract and the requirements for the condition of the System shall be such that it can be demonstrated theoretically in accordance with Appendix 2.1 using equipment failure rate and repair/restore time figures from Table A2.1.1 that mean time between failure and the average outage times at each Delivery Point shall be equal to or better than those calculated at Contract Start, and in accordance with the requirements of Table A2.1.2.
- 4.2.2 When compressed air equipment is replaced the theoretical performance demonstrated by reliability analysis shall be as detailed in Appendix 1.4.

4.3 LU's Verification of Contractor's Compliance

- 4.3.1 LU's verification of compliance with paragraph 4.1 shall be established by provision of actual performance data by both Parties. This data shall be primarily based on SCADA status reports.
- 4.3.2 LU's verification of compliance with paragraph 4.2 shall be established by provision of design performance calculations by the Contractor for each Delivery Point supported by all other necessary details which shall include as a minimum but may not be limited to:
- a) records of equipment fault/failure rates recorded in accordance with the method detailed and the categories of equipment listed in Appendix 2.1; and
 - b) details of operational practices to include maintenance and repair practices.
- 4.3.3 Theoretical calculations shall be undertaken in accordance with Appendix 2.1. The theoretical calculations shall be presented for review audit and/or inspection as required in Schedule 43.3.



5 Emergency Power

5.1 Introduction

5.1.1 The Contractor shall implement the Emergency Supply Plan in accordance with Schedule 9.1 to meet the requirements of this Schedule 5.1.

5.1.2 Statutory Requirements

Without prejudice to any other provision of this Contract, the Contractor shall ensure that the provision and operation of the Emergency Power Supply System complies with or where relevant enables LU to comply with the following:

- a) Electricity at Work Regulations 1989;
- b) The Building Regulations 1991;
- c) Workplace (Health, Safety and Welfare) Regulations 1992;
- d) Safety Signs Regulations 1980;
- e) The Fire Precautions Act 1971;
- f) The Fire Precautions (Sub-surface Railway Stations) Regulations 1989;
- g) HM Railway Inspectorate Railway Safety Principles and Guidance - Parts 1 and 2;

By way of information LU complies with the HM Railway Inspectorate Railway Safety Principles and Guidance by having in place a comprehensive set of engineering standards which are applied to all works which come within the jurisdiction of the RSPGs.

- h) Transport and Works Act 1994; and
- i) Railways and Other Transport Systems (Approval of Works, Plant & Equipment) Regulations 1994.

5.2 Emergency Power Requirements

At all times when required to do so pursuant by clause 9, the Contractor shall provide Emergency Power in accordance with paragraph 5, and comply with the requirements of paragraph 2.6. The Emergency Power Supply System shall meet the following requirements:

- a) Local and Central Emergency Power Supply Systems to support essential lighting in stations in accordance with paragraph 5.2.1;
- b) Central Emergency Power Supply Systems to support essential lighting in emergency Intervention points in accordance with paragraph 5.2.8;
- c) Local and Central Emergency Power Supply Systems to support essential task lighting available within 0.25 seconds and uninterruptible power to communications and other railway operational control equipment in Line and other Control rooms in accordance with paragraph 5.2.3 and 5.2.4;
- d) Central and/or Local Emergency Power Supply Systems to support train radio base stations available within 0.25 seconds in accordance with paragraph 5.2.2;
- e) Local Emergency Power Supplies to the new Lift Public Address System for lift cars in accordance with paragraph 5.2.5;
- f) Local Emergency Power Supply Systems to provide emergency lighting, alarms, ventilation and communications within each lift car and essential lighting required for hand or power-winding in machine rooms at stations in accordance with paragraph 5.2.5;



- g) Central Emergency Power Supply System via the System and LU's Distribution System available for operating essential lifts and escalators in accordance with paragraph 5.2.6 and 5.2.7;
- h) Central Emergency Power Supply System via the System and LU's Distribution System available for the operation of essential drainage pumps and ventilation fans in accordance with paragraph 5.2.9; and
- i) Local and/or Central Emergency Power Supply Systems to support passenger surveillance CCTV systems available within 0.25 seconds in accordance with paragraph 5.2.10;
- j) Central Emergency Power Supply via the System to the Jubilee Line Extension Delivery Points in accordance with paragraph 5.2.11.

The Contractor shall demonstrate that the Capacity of the Emergency Power Supply System is sufficient to meet under evacuation conditions the loads imposed or to be imposed, including on Local Emergency Power Supply Systems.

The Emergency Power Supply System shall be able to supply all equipment connected to it under all conditions. Each Local Emergency Power Supply shall have a spare capacity of 25% provided over and above the capacity required to meet the loads (measured as part of the Emergency Supply Plan), except where agreed in advance with LU. In relation to all of the supplies to be made available pursuant to paragraph 5.1, the specified duration of the Emergency Power Supply System shall not be reduced or varied by any maintenance or checking of equipment forming part of the System being carried out at any time Emergency Power is required, except as clarified in Note 1 to Table 5.1.

The Contractor shall provide Emergency Power in accordance with the following requirements:

5.2.1 Station lighting

At stations listed in Appendix 3A(i), all station lighting fed from the low voltage REC at the Starting Date shall be illuminated in the event of a Power failure to the normal supplies. For the purposes of this paragraph 'normal' supplies means the low voltage REC supply and supplies from or through the System.

The levels of illumination provided by station lighting fed from the low voltage REC supply shall be maintained at all times when the lighting is fed from the Emergency Power Supply System. The Local Emergency Power Supply shall be available within 0.25 seconds of failure of both the REC and System derived Power supplies. The Local Emergency Power Supply System shall continue to be available for a period of not less than one hour.

All Local Emergency Power Supply shall be arranged such that supplies to station lighting cease when either of the normal lighting supplies becomes available.

To the extent that there is any undischarged capacity left in any Local Emergency Power Supply, it shall be possible to use such capacity in any subsequent failure. All Local Emergency Power Supplies shall return to full capacity within a minimum economically practicable time, but no greater than 14 hours, after restoration of power supply to such equipment.

The low voltage REC supply shall remain available to supply the station lighting when the Local Emergency Power Supply is removed from service for repair or maintenance. The operation of these arrangements shall be as agreed with LU in line with the appropriate Interface Procedure(s), Schedule 15.1 (d) or other parts of the Contract.



Remote indication of the status of the Local Emergency Power Supply System shall be provided in the local Station Control Room, or other equivalent location in Stations without a Control Room (e.g. Station Supervisor's Office, Ticket Office, etc.). The remote indication shall have as a minimum, the following functions:

Function Description	LED Colour (Audible Alarm status)	Condition Energised by:
System Healthy	Green (no alarm)	No alarms present in the system - Remote Alarm Unit supplied by LEPS
	Flashing Green (no alarm)	LEPS supply to Remote Alarm Unit lost - supplied by internal battery for 30 minutes. Non latching.
System Fault (including failure on test)	Red (Audible alarm which can be muted locally)	Energised when any of the following faults occur: high DC volts, charger fault*, DC earth fault, battery fault, inverter fault, bypass switch operated, fan failure, inverter control module 'on/off' switch in 'off' position - all operate a latched alarm. *Delayed during recharge following weekly test, also masked during a REC failure.
Battery Discharging	Yellow (no audible alarm)	Energised when battery is discharging (loss of both REC and 'LU' supplies). Non latching.
System test	Yellow (no audible alarm)	Energised when LEPS is being tested by operating battery test push button, also during automatic inverter test. Non latching.
Supply Failure	Yellow (no audible alarm)	Energised by any phase failure on the REC or monitored supply. Non latching.

Remote indication of the status of the Emergency Power Supply System shall have an emergency battery back up power supply of at least 30 minutes duration. The provision of the 'System Fault' function by the remote indication shall be fail-safe.

Where a station has a fire alarm system, each Local Emergency Power Supply System shall be fitted with an internal heat detector linked to the station fire alarm system. Where the local Emergency Power Supply System is installed at a station without a fire alarm panel, volt free change-over contacts shall be provided within the equipment linked to an internal heat detector.

Purpose installed low voltage dc luminaires supplied from batteries via fire resistant cabling (compliant with BS5266 Part 1) may be used as an emergency lighting source where the Contractor is able to demonstrate to the satisfaction of LU that such an installation will provide a sufficient level of escape lighting as required by Fire Precautions (Sub-surface Railway Stations) Regulations.

5.2.2 Train Radio

All train radio base station equipment detailed in Appendix 3A (iii) shall be supplied in the event of a Power failure to their normal supplies, in accordance with Table 5.1.

The Emergency Power Supply System provided to supply the train radio base stations at the stations detailed in Appendix 3A (iii) shall be provided in accordance with paragraph 5.2.1.

Local Emergency Power Supplies to the train radio base stations at the stations detailed in Appendix 3A (iii) are permitted to be combined with the Local Emergency Power Supplies provided to support the essential lighting in stations in accordance with paragraph 5.2.1.



Where the train radio base station Local Emergency Power Supplies are combined with the Local Emergency Power Supply to support the essential lighting, the Local Emergency Power Supply for the train radio base station equipment shall be provided via an additional automatic change-over contactor, where one supply to the additional automatic change-over contactor is provided from the Local Emergency Power Supply system and the other supply is provided from the existing (prior to the installation of the emergency power supply system) train radio equipment power supply.

All train radio supply cables shall be routed through areas of low risk. The following cables and wiring systems shall be used between the Local Emergency Power Supply system and the connected train radio load:

- a) Cables with inherently high resistance to attack by fire:
 - i) Mineral insulated copper-sheathed cable in accordance with BS 6207 part 1. A white PVC sheath is preferred;
 - ii) Cable in accordance with BS 6387. The cable should be at least category B.
- b) Cabling systems having equivalent fire protection. The Contractor is at liberty to offer LU alternative means of "additional fire protection" such as encasement of cabling within concrete, burial or other methods in accordance with building regulations.

5.2.3 Control Room Lighting

5.2.3.1 General

The Local Emergency Power Supply shall be available within 0.25 seconds of failure of both the REC and System derived Power supplies. The Local Emergency Power Supply shall be available for a period of not less than one hour, except as clarified in Note 1 to Table 5.1.

The Emergency Power Supply System shall be arranged such that Emergency Supplies cease to be made available when either of the normal lighting supplies is restored and are then held in reserve for any further failure of the network.

The Emergency Power Supply System shall be arranged such that upon its removal from service for repair or maintenance, the normal REC derived supply shall remain available to the Control Room lighting. The operation of these arrangements shall be as agreed with LU in line with the appropriate Interface Procedures, Schedule 15.1 (d).

5.2.3.2 Requirements for Line & Signal Control Rooms and Interface Switching (Main and Emergency) Power Control Centres

All essential task lighting systems plus emergency lighting as required for safe access / egress to / from the locations detailed in Appendix 3A (ii), - Line & Signal Control Rooms, Miscellaneous Control Rooms, shall be supplied in the event of a power failure to their normal source of supply.

The levels of illumination provided by the Control Room / Centre lighting fed from the low voltage REC supply as at the Starting Date shall be maintained at all times when the lighting is fed from the Emergency Power Supply System.

5.2.3.3 British Transport Police Control Rooms

The levels of illumination provided by the BTP Control Room lighting fed from the low voltage REC supply as at the Starting Date, at the locations detailed in Appendix 3A (ii) - Police Control Rooms, shall be maintained at all times when the lighting is fed from the Emergency Power Supply System in the areas detailed below. Where there is presently insufficient existing REC fed emergency lighting in the areas detailed below, provision of additional emergency lighting, which may be by individual battery luminaries, shall be provided:

- emergency lighting in the Custody Suite (custody area and cells). A minimum of one in four luminaries should be connected to the Local Emergency Power Supply;
- minimal task lighting where computers are powered via the Local Emergency Power Supply *;
- minimal lighting in all operational areas *;
- minimal lighting as required to allow safe access / egress to / from the Control Room location *;

*** Note:** Exact quantities and locations of light fittings to be fed from the Local Emergency Power Supply to be agreed with the Site Landlord on a site by site basis as part of the detailed design.

5.2.4 Control Room Small Power

5.2.4.1 Line & Signal Control Rooms and Interface Switching (Main and Emergency) Control Centres

All the equipment listed below at the locations detailed in Appendix 3A (ii) - Line & Signal Control Rooms and Miscellaneous Control Rooms shall be supplied in the event of a Power failure to their normal supplies, for one hour's duration. The systems to be supported from uninterruptible power supplies are:

- a) all train radio equipment located within the Line Control Centres required to operate the Underground Network under normal and evacuation conditions, unless supported by an existing UPS system;
- b) all BTP and LFEPA radio equipment located within the Control Centres required to operate the Underground Network under normal and evacuation conditions;
- c) all equipment supporting the provision of the Simultaneous Link (SIMLINK) service from the Network Control Centre;
- d) all audio multi-track tape recorder equipment located within Control Centres (this may be provided with a Local Emergency Power Supply with a 0.25 second break, if tests are carried out to prove this does not cause any problems to the normal operation of the equipment);
- e) all essential computer equipment to facilitate the controlled shutdown of [the Underground Network] in the event of power failure;
- f) all desk top computers within Line & Signal Control Rooms to facilitate the controlled shutdown of [the Underground Network] in the event of power failure or where required to operate during a power failure, for the full duration of the failure;
- g) Interface Switching facilities; and
- h) Door entry systems at Line and Signal Control Rooms, where fitted, or an allowance for them where not fitted.



5.2.4.2 British Transport Police Control Rooms

All the equipment listed below at the locations detailed in Appendix 3A (ii) - Police Control Rooms shall be supplied in the event of a Power failure to their normal supplies, for one hour's duration. The systems to be supported from the Local Emergency Power Supply (which shall be available within 0.25 seconds of failure of both the REC and System derived Power supplies where a BTP Control Room has both, or the REC or LU supply where a BTP Control Room only has one supply) are:

- a) Door entry systems, where fitted or an allowance for them where not fitted;
- b) A minimum of two and a maximum of four desk top PCs, to be nominated by the local site Landlord.

5.2.5 Essential Services for Lifts

The following list of systems and circuits ("essential services") for the lifts detailed in Appendix 3A (iv) shall be supplied in the event of the failure of their normal power supplies, in accordance with the requirements of Table 5.1., except where supported by existing battery back-up systems:

- Lighting - Internal lift car, car top (maintenance), machine room, shaft, wheelhouse and pit lighting;
- Ventilation - Lift car ventilation;
- Communication - Lift Emergency Communication System, including Lift Car to Local Station Control room or other equivalent location (where fitted);
- Landing Buzzer / MIP (hydraulic) lift alarms;
- Lift Transfer Circuit;
- Position Sequence Indicator (PSI);
- Lift Passenger Alarms;
- Existing in car CCTV systems where not included in the passenger surveillance CCTV systems as required in paragraph 5.2.10.

The Emergency Power Supply System provided to supply the essential services for the lifts listed in Appendix 3A (iv) shall be in accordance with paragraph 5.2.1.

The levels of illumination provided by lighting within the lift cars and in the associated motor rooms fed from the low voltage REC derived supply as at the Starting Date shall be maintained at all times when the lighting is fed from the Emergency Power Supply System. The Local Emergency Power Supply shall be available within 0.25 seconds of failure of both the REC and System derived power supplies. The Emergency Power supplies shall continue to be available for a period of not less than one hour, except as clarified in Note 1 to Table 5.1.

The Emergency Power Supply System shall be arranged such that supplies cease to be made available when either of the normal lighting supplies is restored and are then held in reserve for any further failure of the network.

The normal low voltage REC supply shall remain available to supply the station lighting when the Local Emergency Power Supply is removed from service for repair or maintenance. The operation of these arrangements shall be as agreed with LU in line with the appropriate Interface Procedure(s), Schedule 15.1 (d).



Supply free issue to the Lift Maintenance Contractor the parts necessary to add public address facilities to each lift car at the stations detailed in Appendix 3A (iv). These shall include, but not be limited to (all parts to LU specification):- a minimum of one loudspeaker per car, lift travelling cable and a termination box.

The new Lift Public Address System * shall be supported from the Local Emergency Power Supply System in the event of power failure.

*** Note:** The LU Approved Communications Contractor will install the new Lift Public Address System.

5.2.6 Lifts

The lifts detailed in Appendix 3A (v) shall be supplied with their full power requirements defined in Appendix 3B from the Central Emergency Power Supply System within 15 minutes following the failure of their normal supplies, in accordance with the requirements of Table 5.1.

5.2.7 Escalators

The escalators detailed in Appendix 3A (v) shall be supplied with the full power requirements defined in Appendix 3B of both drive motors and control systems from the Central Emergency Power Supply System within 15 minutes following the failure of their normal supplies, in accordance with the requirements of Table 5.1.

5.2.8 Emergency Intervention points

Emergency lighting at each of the Intervention points detailed in Appendix 3A (vi), shall be restored within 15 minutes in the event of failure of their normal supplies, as detailed in accordance with the requirements of Table 5.1.

5.2.9 Ventilation Fans and Drainage Pumps

5.2.9.1 Ventilation Fans

Where at the Starting Date the ventilation fans listed in Appendix 3A (viii) are supplied from the low voltage part of LU's Distribution System the Contractor shall ensure that the supply to this equipment is restored from the Central Emergency Power Supply System within 15 minutes in the event of a power failure to their normal supplies, in accordance with the requirements of Table 5.1.

5.2.9.2 Drainage Pumps

The drainage pumps listed in Appendix 3A (vii) shall be supplied from the Central Emergency Power Supply System within 15 minutes in the event of a power failure to their normal supplies, in accordance with the requirements of Table 5.1.

5.2.10 Closed Circuit Television

The passenger surveillance closed circuit television systems listed in Appendix 3A (ix) shall be supplied in the event of power failure to their normal supplies, in accordance with Table 5.1.

The Emergency Power Supply System provided to supply the passenger surveillance closed circuit television systems as listed in Appendix 3A (ix) shall be in accordance with paragraph 5.2.1.

A passenger surveillance closed circuit television system consists of all passenger surveillance monitors in the Station Operations Room, or other similar location (e.g. Station Supervisor's Office), all cameras that supply pictures to the passenger surveillance CCTV system (this may include some dual purpose cameras that are also used for providing pictures to the train drivers), any video recorders that are used for passenger surveillance picture recording purposes and the operating system(s).



Local Emergency Power Supplies to the equipment detailed in Appendix 3A (ix) are permitted to be combined with the Local Emergency Power Supplies provided to support the essential lighting in stations in accordance with paragraph 5.2.1.

Where the passenger surveillance CCTV Local Emergency Power Supplies are combined with the Local Emergency Power Supply to support the essential lighting, the Local Emergency Power Supply for the passenger surveillance CCTV equipment shall be provided via an additional automatic change-over contactor, where one supply to the additional automatic change-over contactor is provided from the Local Emergency Power Supply system and the other supply is provided from the existing (prior to the installation of the emergency power supply system) passenger surveillance CCTV power supply.

All passenger surveillance CCTV supply cables shall be routed through areas of low risk. The following cables and wiring systems shall be used between the Local Emergency Power Supply system and the connected passenger surveillance CCTV load:

- a) Cables with inherently high resistance to attack by fire:
 - I) Mineral insulated copper-sheathed cable in accordance with BS 6207 part 1. A white PVC sheath is preferred;
 - II) Cable in accordance with BS 6387. The cable should be at least category B.
- b) Cabling systems having equivalent fire protection. The Contractor is at liberty to offer LU alternative means of “additional fire protection” such as encasement of cabling within concrete, burial or other methods in accordance with building regulations.

5.2.11 Jubilee extension LVAC Supplies

The Jubilee Line Extension LVAC Delivery Points detailed in Appendix 3A (x) shall be supplied with LVAC power as defined in Appendix 3B from the Central Emergency Power Supply System within 15 minutes following the failure of their normal supplies, in accordance with the requirements of Table 5.1.



Description	Maximum change over time from normal to Emergency Power	Local Emergency Power Supply duration Note 1	Central Emergency Power Supply duration Note 3	Time to return to full Local Emergency Power Capacity	Time to return to full Central Emergency Power Capacity Note 3
Lighting: Stations, Control Rooms, CCTV and essential services for lifts	0.25 seconds	1 hour	7 days	Minimum economically practicable, maximum of 14 hours	Minimum economically practicable, maximum of 7 days
Train Radio Base Stations	0.25 seconds	1 hour	7 days	Minimum economically practicable, maximum of 14 hours	Minimum economically practicable, maximum of 7 days
Line & Signal Interface Switching Control Room Essential Power Supplies	Zero (no break)	1 hour	7 days	Minimum economically practicable, maximum of 14 hours	Minimum economically practicable, maximum of 7 days
BTP Control Room Essential Power Supplies	0.25 seconds	1 hour	7 days	Minimum economically practicable, maximum of 14 hours	Minimum economically practicable, maximum of 7 days
Intervention points Ventilation Fans, Drainage Pumps, Essential Lifts & Escalators and Jubilee Line Extension LVAC Delivery Points	Minimum practicable, no longer than 15 minutes.	Not applicable	7 days without external support.	Not applicable	Minimum economically practicable, maximum of 7 days

Table 5.1 Definition of Emergency Power requirements

Note 1: Minimum requirement is 30 minutes. Quoted figure to accommodate testing, maintenance etc.

Note 2: For the avoidance of doubt, the 15 minute time for Central Emergency Power Supply to be available to certain items of equipment such as Emergency Intervention Points, is intended to define the time limit on the power supply being available. Where additional LU action is required to switch back essential equipment this time is not included within the 15 minutes.

Note 3: On completion of a 7 day run, depending on when this occurred within the 30 year Contract Period a complete overhaul may be needed, before full capacity for another 7 days running can be guaranteed. The cost of that overhaul has not been included and will be treated as a Variation under Clause 23 if required.