

Category 1 Standard

S1110 AC Electrical Protection Requirements

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1 Purpose

This Standard:

- a) describes the minimum performance levels required of electrical protection on London Underground's (LU's) Alternating Current (AC) power distribution systems;
- b) gives details of protection systems in terms of design principles and methods;
- c) defines the requirements for all electrical protection equipment for power system circuits operating normally at or above 400V AC between conductors; and
- d) provides the underlying principles applicable to protection systems in achieving minimum levels of safety, supply continuity and stability for AC power systems on the London Underground Power Distribution Network.

2 Scope

2.1 This Standard shall apply to London Underground's 22kV, 11kV, 600V and 400V AC distribution systems and any assets that form part of the Power PFI Contractors Operation and Maintenance responsibilities. The standard also lays down specific protection requirements associated with the Bulk Supply Points (BSP) and LU's Emergency Generation Facility.

2.2 This Standard includes the requirements for:

- a) protection systems;
- b) protection relays;
- c) direct acting protective devices;
- d) electronic protection within circuit breakers; including Moulded Case Circuit Breaker (MCCB).
- e) fuses;
- f) protection current and voltage transformers;
- g) protection communications and intertripping;

2.3 This Standard specifically excludes any requirements for protective equipment on-board rolling stock.

3 Requirements

3.1 Performance requirements

3.1.1 General

3.1.1.1 Each electrical protection system shall be designed, specified, supplied, installed, commissioned maintained and decommissioned correctly throughout the life of the system.

3.1.1.2 Electrical protection shall operate satisfactorily when in the electrical and physical environments found on London Underground's network.



Note: Refer to Powerlink Specification SP82603 for LU substation environments.

3.1.1.3 Relay enclosures shall provide a minimum degree of protection IP52 indoors, IP55 outdoors to BS EN 60529 unless otherwise specified.

3.1.1.4 Electrical protection shall be such that the requirements set out in S1105 can be achieved.

3.1.1.5 It is the responsibility of all parties, when installing a new protection system, to agree the arrangements necessary to ensure compliance with Electro Magnetic Compatibility (EMC) standards and in particular LU standards 1-222 and 1-193.

3.1.2 Operational

3.1.2.1 Electrical protection systems shall:

- a) always operate as necessary to minimise danger to personnel and damage to plant when excess current above the withstand capability of plant or a fault occurs in any part of the electrical power system;
- b) as far as is reasonably practicable, operate when a fault or condition occurs for which the designer intends operation;
- c) as far as is reasonably practicable, not operate when no fault condition occurs or when a fault or condition occurs and the designer intends it to be dealt with by operation of another protection system;
- d) ensure discrimination is achieved with upstream protection of the incoming electricity supply and at the interface with the Low Voltage (LV) system through the application of relevant settings and co-ordination.

3.1.2.2 Protection systems shall be designed such that they operate in accordance with the requirements of this standard for both normal and credible power system outage and system operating conditions.

3.1.3 Reliability

The reliability of electrical protection systems shall be verified by inspection and testing throughout its life from manufacture through to decommissioning. This will be achieved through monitoring the protection system performance for correct operation on both internal and through faults as outlined below:

- a) type testing and certification;
- b) factory performance tests on complete protection systems or if this is not possible on major sub-systems prior to delivery to site;
- c) site testing and inspection for commissioning purposes. The complete system shall be tested including all transducers, Current Transformers (CT's), Voltage Transformers (VT's) and associated circuitry;
- d) periodic inspection and testing of systems in service to monitor deterioration in service;
- e) systematic review of protection operations in service for all internal and external faults in order to validate performance.

3.1.4 Selectivity

Protection systems shall only open the minimum number of circuit breakers necessary to prevent danger and to isolate a fault in order to minimise system disruption and any potential loss of power.



3.1.5 Speed of Operation

3.1.5.1 HV Main Protection systems shall be designed to operate as rapidly as reasonably practicable whilst still maintaining discrimination. However, the fault clearance time in all reasonably foreseeable circumstances shall not be greater than 250 milliseconds.

3.1.5.2 HV Back Up Protection systems (including Remote Back Up) and LV Protection systems shall be designed to operate as rapidly as reasonably practicable whilst still maintaining discrimination. However, the fault clearance time in all reasonably foreseeable circumstances shall not be greater than the least of:

- a) 3 seconds;
- b) the primary and secondary equipment withstand capability;
- c) the requirements of the electricity supplier.

Note: For exceptional circumstances only, in line with the requirements of BS 7671, LV systems only are permitted to have operating times of up to 5 seconds.

3.2 General design requirements

3.2.1 Main Protection

Main Protection shall be provided for all plant and equipment and may be of the unit or non unit type. Main Protection shall be arranged with overlapping zones of operation in order that no part of any equipment is reliant solely on back-up arrangements for protection.

Note: This may result in additional protection systems being provided to cover such eventualities as when all CT's are installed on only one side of circuit breakers such that overlap of circuit breakers is not achieved.

3.2.2 HV Back-up Protection

HV Back Up Protection shall be provided to cover for the potential non operation of any Main Protection system. It is permissible for either the selectivity or the speed of operation to be lower than the Main Protection but overall clearance time shall remain within the limits defined in Section 3.1.5.2 of this document.

3.2.3 HV Remote Back Up Protection

3.2.3.1 HV Remote Back Up Protection shall be provided such that in the event of a single point failure of the protection system, faulty power circuits can still be disconnected. It is permissible for either the selectivity or the speed of operation or both to be lower than the first back up protection expected to operate but overall clearance time shall remain within the limits defined in clause 3.1.5.2 of this document wherever reasonably practicable.

3.2.3.2 HV Remote Back Up Protection shall be provided to ensure that the performance requirements in clause 3.1.5.2 above are achieved reliably wherever reasonably practicable when Main and Local Back-up Protection have responded correctly to the fault, but a circuit breaker has failed to operate correctly.

3.2.3.3 At BSP's and 22kV switch-houses, the use of breaker fail protection shall be provided, to ensure backup protection against a circuit breaker failing to trip.



Note: The designer shall also consider the inclusion of breaker fail protection at other locations where its application can be justified on operational and economic grounds. This often being an inherent feature of modern microprocessor based relays.

3.2.4 Protection Settings

Protection Settings shall be selected after taking cognisance of the following factors:

- a) compliance with section 3.1 of this document;
- b) protection transformer characteristics;
- c) impedances of secondary wiring;
- d) maximum and minimum system fault levels;
- e) power system impedances;
- f) load currents including starting and stalling currents;
- g) relay rating and setting range;
- h) discrimination with associated systems;
- j) power system stability;
- k) plant and equipment ratings including secondary equipment;
- m) circuit breaker clearance times;
- n) back up protection co-ordination;
- p) performance under contingency non standard operational conditions;
- q) other relevant factors as may be deemed appropriate.

3.2.5 Auxiliary Power Supplies

3.2.5.1 Auxiliary power supplies for main protective devices shall be separately fused from back up protective devices.

3.2.5.2 At Distribution Sites auxiliary power supplies shall be distributed through HV switchboards using two separate bus wires per switchboard section. Main protective devices shall be supplied off one bus wire and back up protective devices supplied off the other wire. Multiple circuit breaker trip coils shall be split across the bus wires.

3.2.5.3 For HV switchboards at non- Distribution Sites or all LV switchboards auxiliary power supplies shall be distributed through switchboards using a single bus wire per switchboard section. Main and backup protective devices and circuit breaker trip coils shall be supplied from the bus wire but separately fused.

Note: Refer to Attachment 7.2 for illustrative examples of clauses 3.2.5.1, 3.2.5.2 and 3.2.5.3.

3.2.5.4 If protection systems require high-integrity auxiliary power supplies, such as ac or dc power for internal electronic circuitry or for operating circuit-breaker trip coils, the status of such supplies shall be monitored as close as possible to the point at which auxiliary power is required, or in such a way as to be able to detect failure of the supply at any point between the source and the point of use.

3.2.5.5 If any auxiliary power supplies fail, a remote indication via the Supervisory Control and Data Acquisition (SCADA) system from an associated flag relay at the point of failure shall be given, but the protected zone of the power system shall not be disconnected.



- 3.2.5.6** Trip Circuit Supervision and Protection Supply Supervision relays shall be applied to all High Voltage (HV) circuits of 11kV and above.
- 3.2.5.7** At strategic points, BSP's and 22kV switch-houses, the designer shall provide duplicate battery and charger systems. These shall be cross connected to provide main protection from one battery source and local backup protection from the other.
- 3.2.5.8** In the case of multiple parallel feeders the main protection tripping will be divided equally between battery systems where reasonably practicable.
- 3.2.5.9** At strategic points, BSP's and 22kV switch-houses, the designer shall provide duplicate trip coils on circuit breakers.
- 3.2.5.10** Substation AC or DC protection equipment supplies shall feed through separate fuses and links. When the fuses and links are withdrawn the protection and control circuit shall be completely isolated.
- 3.2.5.11** Auxilliary supplies to functional circuits (panels) shall be arranged such that a fault on a control circuit does not interrupt supplies to protection equipment circuits.
- 3.2.5.12** The closing circuit for the functional circuit (panel) shall be sub-fused off the tripping circuit to maximise the ability to open the circuit breakers in an emergency or through protection operation before a closing operation takes place. Fuses shall be graded accordingly to afford discrimination.
- 3.2.5.13** DC supplies shall be nominal 110 volt.

3.2.6 DC Relays

3.2.6.1 Trip Relays

- a) circuit breakers at 11kV and above shall be tripped via a trip relay and not directly from the protection relay;
- b) direct tripping from the protection relay may be used as a back up to the trip relay at 11kV and above . For other applications direct tripping from the protection relay is permitted subject to the relay being adequately rated for the purpose;
- c) trip relays shall have sufficient contacts to fulfil all of the requirements required of it in addition to the tripping function;
- d) Contacts shall be robust enough to make, carry and break trip coil current should circuit breaker auxiliary contacts designed to interrupt trip coil current fail when the circuit breaker is tripped;

Note: Contacts of the magnetic blow out type may be required and are often used for this purpose.
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- e) trip relays may be of the self reset with delayed drop off, manually reset or electrically reset types depending upon the application;
- f) trip relays shall not operate through capacitance currents. The minimum operating current of trip relays shall be 50mA for 110 volts dc;

Note: This may be achieved through double pole switching of the relay coil or by minimising the amount of connected wiring in circuit.

- g) performance requirements are laid down in ENA (TS 48-4);



- h) the maximum operating time must not exceed 10 milliseconds at rated operating voltage.

3.2.6.2 General Purpose DC Relays

Where such relays are utilised for supply supervision, interposing, repeat and control:

- a) for relays connected in nominal 110 volt DC systems the relay shall operate in the range between 87.5 and 137.5 volts;
- b) tripping circuits shall be designed such that tripping will occur with 50% of the rated DC supply voltage applied
- c) closing circuits shall be designed such that successful closure will be achieved with 80% of the rated DC voltage applied.

Note: The IEC 60255 suite of standards cover this range of operating voltages.

3.2.7 Lockouts

A Lockout (requiring a local hand resetting of relays prior to circuit re-energisation) shall only be provided for the following:

- a) HV busbar faults detected by unit protective systems;
- b) HV transformer, HV transformer feeder and rectifier faults detected by high set overcurrent protection;
- c) HV final circuit earth faults (i.e. transformers, transformer feeders and rectifiers);
- d) rectifier reverse current faults;
- e) overpressure devices on transformers and the surge element of Buchholz gas and surge relays;
- f) transformer faults detected by unit protective systems;
- g) in order to maintain a level of operational flexibility, operation of unit protection on distribution cables will not lockout.

Note: Where a lockout feature does not exist operational procedures should be in place defining clearly when manual reclosure can be attempted and the exceptional circumstances when this can occur.

3.2.8 Unit Protection and Intertipping Pilot Requirements

3.2.8.1 Unit protection applied to feeders shall be based upon the use of private pilot circuits which provide a metallic conductive path between the two ends of the feeder being protected.

3.2.8.2 Any specific performance characteristics for the pilot circuit shall be considered as part of the design.

3.2.8.3 Alternative schemes based upon different methods of achieving the end to end comparison and signalling (e.g. voice frequency (vf) channels or fibre optics) shall be considered where existing metallic pilot circuits are inadequate or unavailable.

Note: The characteristics of pilot circuits should be checked following interruption to ensure that protection capability has not been impaired.



3.2.9 Pilot supervision requirements

3.2.9.1 Intertripping and protection pilot circuits shall be provided with continuous supervision to detect any loss of capability or pilot circuits, including open circuits, crossed connections and short circuits. Such supervision systems shall provide an alarm indication via the SCADA system.

3.2.9.2 Faults on pilot circuits used for intertripping shall not cause tripping of the protected equipment or circuit except on HV transformer feeders where local back up protection is not fitted.

3.2.9.3 Operational procedures shall be in place indicating the action to be taken following the loss of pilots used for protection and intertripping.

3.2.10 Protection Transformers

3.2.10.1 Protection transformers shall be adequately rated to accept the burden of the entire secondary circuit including the interconnecting leads and the connected protection equipment at any relay setting and any fault current up to the maximum switchgear rating.

Note	Care to ensure that relay ratings are matched to current transformer rating is particularly important.
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3.2.10.2 Each group of current transformer circuits electrically separate from other circuits shall be single point earthed through an independent earth link; such earth links shall be secured so that they cannot be inadvertently disconnected when danger would occur (e.g. those providing earth connections for transformer secondaries).

3.2.11 Facilities required for inspection, maintenance and testing

Shall include the following:

- a) where relays are housed in draw-out cases with Current transformer (CT) connections, they shall have shorting contacts wherever possible, enabling the defective unit to be replaced quickly with minimum disruption;
- b) individual circuit protection schemes shall be kept as electrically separate as possible, and the use of common wires between circuits should be avoided except where these are essential to the correct functioning of common substation circuits (e.g. interlocking, busbar protection);
- c) a single auxiliary switch or relay contact shall not be used for opening or closing more than one circuit and; where practicable auxiliary switches should be duplicated;
- d) test blocks shall be provided for every relay having a protection function. In cases where relays form a functional group such as a feeder Unit Protection scheme - a single test block may be supplied to simplify testing;
- e) test blocks shall provide connections for current transformer test windings if fitted; and
- f) test blocks shall facilitate circuit current and voltage measurements to be taken safely with the power circuit in service;

Note:	The designer should also consider other relevant factors as may be deemed appropriate
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3.3 Bulk Supply Points (BSP's)

- 3.3.1** The prime requirements for the protection of incoming circuits to BSP's are determined by the Distribution Company in order to comply with The Distribution and Grid Codes and to meet their own internal standards.
- 3.3.2** Bulk Supply Transformers shall incorporate the protection requirements set out in Section 3.8 of this Standard.
- 3.3.3** LU require directional overcurrent and earth fault protection to be applied to the secondary side circuit breakers of all BSP transformers in addition to other protective systems needed to meet the requirements of this standard.
- 3.3.4** Where pilot cables are used to provide intertripping, the pilot cables for each transformer shall be installed in separate diverse cable routes if practically achievable.
- 3.3.5** Where BSP's are fed from diverse sources of supply means of protection against through fault currents between transformers shall be provided.

3.4 Generator Circuits

- 3.4.1** The fundamental requirements for the intended use of Generation from Greenwich is to support Central Emergency Power Supply (CEPS) operation. Protection system requirements must ensure that this requirement can be adequately achieved.
- 3.4.2** Requirements for generator protection also have to accord with the Grid and Distribution Codes for the operation of generation into the Distribution Network and Grid system.
- 3.4.3** Generator protection shall include the following features:
- a) overall differential Unit Protection covering the generator and its generator transformer;
 - b) reverse power protection;
 - c) overvoltage and undervoltage protection;
 - d) overspeed protection;
 - e) neutral voltage displacement if appropriate;
 - f) Rotor Earth Fault;
 - g) Stator Earth Fault;
 - h) Negative Phase Sequence;
 - j) Field Failure.

Note: The designer should also consider other relevant factors as may be deemed appropriate
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- 3.4.4** In addition for parallel operation with the grid system the following protection needs to be applied:
- a) loss of Grid Protection during parallel operation;
 - b) overspeed protection.
 - c) pole slip protection.