

Guidance Document

G0127 Substation and Transformer Room - Design Guidance

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1 Purpose

- 1.1 The purpose of this Guidance is to support various LU and Powerlink Engineering Standards to clarify the interconnection and operation of the major items of electrical equipment in a substation or transformer room.

2 Scope

- 2.1 This Guidance applies, in general, to the majority of substations and transformer rooms on the System which might be described as of “standard” design. As such it is targeted at the major plant items in substations and transformer rooms under the control of, or intended to become under the control of, Powerlink.
- 2.2 It is recognised that this Manual will not cover all aspects of the design of substations and transformer rooms, nor many aspects of the design of “non-standard” substations and transformer rooms (e.g. a transformer room with only a single transformer). Its intent is to provide the majority of answers to designers whose questions cannot be readily answered by reference to the relevant Standards.
- 2.3 The expected users of this manual are the designers of proposed reinforcements or other changes to substations and transformer rooms on the System as well as the designers of new substations or transformer rooms. These designers could be Powerlink and its contractors or LU and its contractors or third party providers.

3 Guidance

3.1 Introduction

- 3.1.1 Whilst there are LU and PL Standards for LVAC & HVAC switchgear, HV/LV auxiliary transformers etc, there is little formal design guidance on how this equipment should be interconnected and operated.
- 3.1.2 As more 3rd parties (i.e. other than Powerlink) become involved in supplying extensions and reinforcements to the System, there is a need to introduce some general design principles for the substation or transformer room as a whole such that these facilities from the various providers are generally similar in their basic function and operation.
- 3.1.3 3rd party built or renewed substations and transformer rooms will be put into service under the auspices of Powerlink and as such will need to be “adopted” by Powerlink. It is thus important for LU to “get it right first time” at minimum cost to LU whilst delivering onto the System a facility of known quality, function and risk profile for Powerlink to operate and maintain.

3.2 General Requirements

- 3.2.1 This document is envisaged to mainly cover the AC aspects of the majority of new and substantially refurbished switchhouses, substations and transformer rooms on the System with two or more auxiliary transformers – although alternative arrangements are touched on. It covers the primary items of plant from the HV switchboard down to the InfraCo level.
- 3.2.2 This document is thus designed to be a brief overview of how the components of such a substation or transformer room fit together to ensure a consistent approach to the design (and thus operation) of such new facilities. This document cannot cover all



possible configurations of equipment – but should serve as a guide to the intention of LU as to the design of these facilities.

- 3.2.3 The reliable supply of power is obviously essential to the running of the railway and getting the design of these facilities right the first time helps get LU value for its money.
- 3.2.4 Many of these requirements are already, to some extent, included in other Standards (Powerlink and/or LU). The principal relevant Standards are noted in each section. Should there be any conflict between this document and the provisions of a specified existing Powerlink or LU Standard, then the requirements of the LU Standard shall prevail.
- 3.2.5 A single line diagram for a typical substation or transformer room is included as Sketch 1 in Section 5.1.
- 3.2.6 The LU, Powerlink and any national Standards particularly applicable are included in each section. A more comprehensive list of Standards is included in the References section.

3.3 Operational Interlocking

- 3.3.1 There should generally be no electrical or mechanical interlocking on HV (22kV, 11kV) or Powerlink LV switchboards to prevent paralleling of equipment within substations or transformer rooms. Any need to prevent or control paralleling is controlled by Powerlink Operational Procedures.
- 3.3.2 An exception to this would be where interlocking is necessary to prevent the inadvertent paralleling of HV supplies from different BSPs (e.g. JLE).
- 3.3.3 Note that safety interlocking – e.g. interlocking earth switches and isolators – is a separate topic and addressed in the relevant switchgear standards.
- 3.3.4 Switching interlocks between voltage levels are similarly excluded with the exception of between the HV and DC CBs on a rectifier/transformer which are described in Table 1.
- 3.3.5 It is noted that interlocks downstream of a PL DP may be needed where this supply feeds a load which has an alternative DNO supply – i.e. a break before make changeover switch is usually necessary to avoid paralleling the two supplies on the LU switchboard.

3.4 Auto-Close, Auto-Reclose, Auto-Changeover

- 3.4.1 There will generally be no auto-close or auto-reclose schemes at HV or Powerlink LV level to automatically restore power supplies following an equipment trip in substations or transformer rooms.
- 3.4.2 An exception may be where LV supplies in a substation or transformer room are derived from different BSPs (i.e. with consequently separate HV supplies in the substation or transformer room); loss of an HV supply in this case may warrant an auto-close (auto-changeover) of the LV bus section to restore all LV supplies (e.g. JLE) in as short a time as practicable.
- 3.4.3 Another exception exists on the Victoria Line where an 11kV ring supplies a chain of transformer rooms; when the duty transformer is lost the standby transformer is automatically switched in.
- 3.4.4 Auto-changeover at LV downstream of the Powerlink or InfraCo main distribution switchboard is common local to the load where an immediately available back-up supply is required – e.g. lift auxiliary supplies, tunnel lighting etc. See 1-123 for further details of such arrangements.



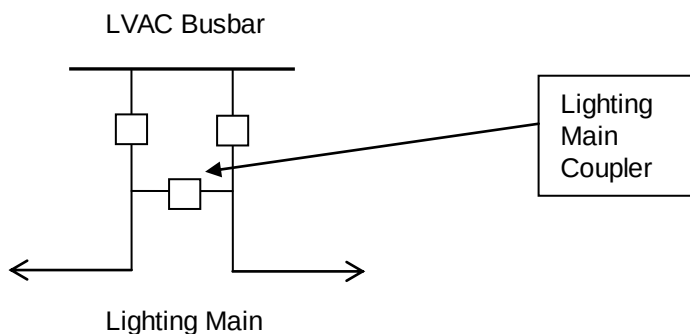
3.5 Electrical Configuration

- 3.5.1 In a substation or transformer room with two auxiliary transformers (i.e. the vast majority of such installations), the normal (system intact) operating configuration will have two sections of busbars, connected via a bus-coupler. (Sketch 1 refers):
- 3.5.1.1 HV bus – all CBs closed (except in very few cases where an open point is necessary to avoid the paralleling of BSPs)
- 3.5.1.2 LV bus – all CBs closed (unless such an arrangement gives excess fault level or protection problems for any InfraCo LVAC switchboards downstream of the Powerlink LVAC main switchboard – see 3.5.1.3 below),
- 3.5.1.3 LV bus – one auxiliary transformer CB open (to give one transformer on load supplying all the LV switchboard load and the other transformer on “hot standby”) or the LV bus section CB open (to give both transformers on load each supplying half the LV switchboard).
- 3.5.2 Where the LV bus is operated as in 3.5.1.3 above, upon the loss of a transformer supplying load, the SSE, after carrying out appropriate checks, will remotely switch in the other transformer or close the LV bus section as appropriate. It should be noted that, as defined in the PSC, this arrangement is deemed to provide N-1 reliability (N-1 reliability is where the unplanned loss of any one item of equipment such as a feeder, transformer or section of bus does not affect the supply of power from any Delivery Point - DP) at the Powerlink LVAC bus – even though there will obviously be a short break in the supply of power from some DPs whilst the SSE completes the switching operation.
- 3.5.3 In all cases however, the LV switchboard should be capable (including fault rating) of operation with all LV CBs closed (i.e. both transformers operating in parallel). This configuration will occur when “changing over” the transformer on load under the configuration in 3.5.1.3 but this arrangement may become also the normal configuration at some time in the future when operational restrictions allow (e.g. removal of downstream fault level problems) to improve supply availability and/or effect savings in transformer losses and thus improve LUs carbon footprint.
- 3.5.4 Whilst a substation will normally house both the HV as well as the LV switchboard, it is not uncommon in transformer rooms to only have the LV switchboard along with the auxiliary transformers – i.e. the transformers are cabled directly to a remote HV switchboard (transformer ended feeders).
- 3.5.5 Note that a cost effective solution to a relatively small load could be a single transformer installation. However, the acceptability of this would depend upon the availability of back-up power supplies. Single transformer solutions using an RMU and no SCADA have proven cost effective in certain circumstances where it applies to single discipline (e.g. signalling) functional loads that are operationally critical and where a DNO supply is available on a UPS buffered change-over switch. Such solutions are usually only considered towards the extremities of the System. Dual transformers are always provided where the load is station related and multidisciplinary.
- 3.5.6 Note also that adding a third transformer to a two transformer site is an acceptable alternative to, say, replacing the existing transformers with larger units. This has proved cost effective at some sites.
- 3.5.7 **Relevant Standards:**
- | | |
|---------|--|
| SP81802 | Security Planning Criteria for the Powerlink System |
| SP80001 | General Requirements for Fixed Installation Power Supply Equipment (E4013A1) |

1-123 Requirements for Matching Electrical Loads to Supplies when making changes to Low Voltage Infrastructure.

3.6 Reliability of LV Supplies

- 3.6.1 Prior to the disaggregation of the LU System in the late 1990s (i.e. start of the PSC), the LVAC busbars in substations and transformer rooms were the final LV supply and distribution level – i.e. supplies from these switchboards (now the Powerlink Delivery Point level) fed large loads directly (mostly substation loads such as compressors and large station loads such as lifts and escalators) as well as lighting mains and other feeds to station supply boards. As such, the source of these feeds (from the Powerlink substation and transformer room LVAC switchboards) have approximately the same N-1 reliability of the Powerlink LVAC bus.
- 3.6.2 There is now a tendency (driven by the demarcation of switchboard ownership with respect to operation and maintenance being carried out by different entities) to install an additional level of LVAC distribution in new and refurbished installations – i.e. physical separation of Powerlink and non-Powerlink LVAC distribution switchboards. This usually results in relatively large LV feeders from the Powerlink LVAC bus feeding, for example, an InfraCo LVAC distribution switchboard located in InfraCo premises which then in turn feeds the different switchrooms within the station. The lighting mains normally continue to be fed directly from the Powerlink switchboard as Powerlink are responsible for the protection of the lighting main cables.
- 3.6.3 In order to preserve the reliability of station power supplies, these InfraCo LVAC distribution switchboards should have feeding arrangements such that they have a similar level of reliability (i.e. N-1) to the Powerlink LVAC switchboards from which they are supplied. This usually results in duplicate LVAC feeds (one from each LVAC bus section) to these additional distribution switchboards from the Powerlink LVAC switchboard.
- 3.6.4 This arrangement is also necessary to permit the ready maintenance of any equipment without loss of any final power supply (which may necessitate a station or Line closure).
- 3.6.5 Notwithstanding the tendency towards additional levels of LVAC switchboards as outlined above in 3.6.2, LUs strong preference is for the single main switchboard arrangement of 3.6.1 as this is likely to result in lowest total overall cost giving cognisance to the requirement of CEPS segregation outlined in 3.8 below.
- 3.6.6 Whilst there is N-1 reliability at the LVAC bus as outlined above, there is no redundancy on the supply side of a switch feeding a circuit supplied from that bus. Where N-1 reliability is required on the supply side (to supply, say, a lighting main running through a station), a common cost effective configuration is given below:



3.6.7 Relevant Standards:

SP81802 Security Planning Criteria for the Powerlink System



SP80001 General Requirements for Fixed Installation Power Supply Equipment (E4013A1)

1-124 LV AC & DC Power Supply Parameters, Characteristics and Performance Requirements

1-123 Requirements for Matching Electrical Loads to Supplies when making changes to Low Voltage Infrastructure.

3.7 Quality of Supply

3.7.1 The quality of power at Powerlink DPs is different to that available from a DNO originated supply. Whilst the power quality from the DNO is governed by the various Standards relating to the public electrical power supply, the Powerlink System is not a public supply and is governed by other Standards. The principal differences are:

Item	Power Quality at LVAC	
	DNO	Powerlink/LU
Normal Voltage Range	400/230V +/- 10%	400/230V +10%, +2%
Harmonic Planning Levels % (3rd, 5th, 7th, 11th, 13th, THD)	4, 4, 4, 3, 2.5, 4	5, 6, 6, 4.5, 4, 7

3.7.2 Relevant Standards:

BS EN 50160 Voltage Characteristics of Electricity Supplied by Public Distribution Networks

G5/4-1 Engineering Recommendation – Planning Levels for Harmonic Voltage Distortion

IEC 61000-2-4 Electromagnetic compatibility (EMC). Environment. Compatibility levels in industrial plants for low-frequency conducted disturbances

3.8 CEPS/Non-CEPS Supplies

3.8.1 LVAC loads will be classified as CEPS or Non-CEPS as appropriate (CEPS = Class A supply which supplies Category 1 loads and Non-CEPS = Class B supply which supplies Category 2 loads all as defined in Standard 1-123).

3.8.2 Non-CEPS loads are required to automatically trip upon loss of supply voltage – i.e. the switching device controlling the load must be fitted with an undervoltage trip (normal setting 0.7Un, 3 sec).

3.8.3 This often results in the provision of separate CEPS and Non-CEPS InfraCo switchboards so that a single undervoltage device can control many such loads (rather than fitting an undervoltage trip to each individual load supply).

3.8.4 Both the CEPS and Non-CEPS switchboards should have similar security levels to the supply switchboards as discussed in the above section. If the under-voltage relays are fitted in the Powerlink switchboard on the circuits feeding the Non-CEPS switchboard (the preferable arrangement) then the SSE can reclose the circuit at an appropriate time using the SCADA. This means the SSE can restore normal supplies as soon as they become available following an incident and the station does not have to wait for a suitably qualified person arriving at the station to reset the undervoltage relay and restore supplies.

3.8.5 It is noted that load increases on the System are controlled by Powerlink and LU by their Load Application process where all proposed new loads are formally applied for