ENGINEERING OPERATING STANDARD

EOS 04-0035

COMPACT SUBSTATIONS

Network(s): EPN, SPN

Summary: This standard details the use of compact (pad-mount) substations on the 11kV and 6.6kV networks.

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☐ UK Power Networks Services
☒ Contractors
☐ ICPs/IDNOs
☐ Meter Operators
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**Why has the document been updated:**

- Minor version update
- Introduction of a new range of compact substations
- Periodic review

**What has changed:**

- Cable termination revised (Section 6.1).
- Connection of single-phase pad-mount substations incorporated from EDS 08-0127 (Section 6.2).
- Earthing requirements revised to align with earthing standards (Section 6.3).
- HOT site requirements included (Section 6.4).
- Operational detail from bulletin HSS 406 OB 150 added (Section 8).

Document restructured and title amended.

Original document replacing EI 4/1/2, EI 4/3/2 and EDM V13/S2/3ss3
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1 Introduction

This standard details the use of compact substations rated from 50kVA to 315kVA on the 11kV and 6.6kV networks. The current range of compact substations are supplied by CG Power Systems (previously Pauwels Trafo Ltd).

2 Scope

This document applies to all compact substations used on the 11kV, 6.6kV and 3kV networks and includes the range of substations previously known as compact, micro, pad-mounts and mini substations.

3 Glossary and Abbreviations

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<tr>
<td>HV</td>
<td>High-voltage</td>
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<td>UK Power Networks</td>
<td>UK Power Networks (Operations) Ltd consists of three electricity distribution networks:</td>
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<tr>
<td></td>
<td>• Eastern Power Networks plc (EPN).</td>
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4 Application

Compact substations may be used where an 11kV or 6.6kV ground-mounted transformer is required with a rating up to 315kVA and a ring main unit is not required. They are designed for direct tee-off cable connection to the 11kV or 6.6kV distribution network. They may also be used to replace existing free-standing pole transformers.

100kVA and 200kVA compact substions are also used on 3.5kV networks.

Refer to EDS 08-3000 for all aspects of HV network design including the use of compact substations and the exclusions.

5 Equipment Description

5.1 Overview

UK Power Networks compact substations (Figure 5-1 and Figure 5-2) are ground-mounted, self-contained, cable-connected prefabricated substations that do not include HV switchgear.

Compact substations are supplied complete with an integral enclosure which requires no further enclosure or fence unless required by a risk assessment.

The door is secured by a padlock in a recess in the door. A feeder pillar key is used to remove the recess cover plate. To unlock the unit rotate the key anti-clockwise (standard unlocking). **Note:** To unlock the older SPN units rotate the key clockwise.

Access to both the LV and HV compartments is via a door at the front of the unit. The LV compartment is on the left-hand side and the HV compartment is on the right-hand side.

The transformer tank is sealed with an air-space at the top to absorb pressure variations. A pressure relief valve is fitted in the transformer top which vents into the space below the enclosure roof.
5.2 Ratings

The compact substation range is split into two categories:

- Compact substations up to and including 100kVA, previously referred to as micro or pad-mount substations (Figure 5-1).
- 200kVA and 315kVA compact substations previously referred to as mini or compact substations (Figure 5-2).

The main difference between the two categories is the protection. Compact substations up to and including 100kVA contain a single set of LV fuses whereas the 200kVA and 315kVA compact substations include a three-way LV panel and HV Bay-O-Net fuses (Section 8.4).

Compact substations currently range in size from 50kVA single-phase up to 315kVA three-phase. Single-phase units are supplied as split-phase only. Therefore if a 50kVA single phase supply is required, a 100kVA transformer shall be used and connections made to one side only. A full list of sizes can be found in EAS 00-0004.
Figure 5-3 – 50/100kVA Compact Substation with HV Cable Box

Figure 5-4 – 50/100kVA Compact Substation with Separable Connectors
5.3 **Unit Dimensions**

General arrangement drawings including dimensions are included in Appendix A.

5.4 **Site Dimensions and Foundations**

5.4.1 **Land Acquisition and Siting**

Compact substations shall be positioned on the site such that there is a minimum 1.0m clearance to the front of the substation for operational purposes and a 0.5m clearance around the back and sides for maintenance and cooling.

5.4.2 **50kVA and 100kVA Compact Substations**

The maximum footprint of compact substations up to and including 100kVA is 1.2m by 1.1m. In order to provide sufficient clearance for the operation and maintenance of the substation it is necessary to acquire rights over an area of land 2.2m by 2.6m.

5.4.3 **200kVA and 315kVA Compact Substations**

The maximum footprint dimension of the 200kVA and 315kVA compact substation is 1.8m by 1.3m. In order to provide sufficient clearance for the operation and maintenance of the substation it is necessary to acquire rights over an area of land 2.8m by 2.8m.

5.4.4 **Foundations**

Refer to EDS 07-3102 for details of the plinth size. If necessary path edging shall be installed externally around the cable entry area and the void beneath the HV and LV cable terminations shall be filled with a weak mix of sand and cement.
6 Installation
6.1 Cable Terminations

6.1.1 HV Connections

New HV connections shall be made using an 11kV 95mm² three-core triplex cable terminated onto the HV bushings in accordance with the 11kV Jointing manual using either:

- Type A separable connectors.
- Bolted connections in an integral air insulated HV cable end box.

Note: In all legacy compact substations the HV cable was terminated in the integral air insulated HV cable end box secured using bolted lugs.

6.1.2 LV Connections

All compact substations will accept a LV cable up to 300mm². The LV cable shall be terminated in accordance with the LV Jointing manual.

6.2 Connection of Single-phase Compact Substations to Overhead Line Networks

6.2.1 Background

The introduction of single-phase compact substations has led to an increase in the number of occasions where a single-phase HV underground network extension is required. The normal method of connection has been via a three-phase PICAS cable (in SPN) or three single core polymeric cables (in EPN). In both cases only two cores are used, leaving the third phase available for possible upgrade to a three-phase system in the future.

All cable connections to single-phase compact substations within UK Power Networks shall now be made using three-core triplex 11kV cable.

The charging currents created by sections of single-phase circuit within a three-phase system gives rise to unbalanced voltage that needs to be contained. The connection of an unused core within a single-phase section of network will increase the level of unbalanced charging current and contribute to higher voltage unbalance.

For circuits that are supplied from an arc suppression coil system, the value of capacitive current will affect the ability to operate the coil within the design limits and therefore the introduction of additional capacitive currents through the connection of unused cores in single-phase networks is not desirable.

There are also limits on the length of underground cable that can be connected to single-phase overhead lines and these are detailed in EDS 08-3000. New single-phase connections that require greater than 100m of underground cable may require upstream network reinforcement and shall be specifically assessed to ensure compliance with EDS 08-3000.

6.2.2 New Connections to a Single-phase Compact Substation

In single-phase compact substations the cable end box allows the connection of all three cable cores. The third spare core shall be connected to the ‘spare’ centre bushing using a standard termination (Section 6.1.1).
6.2.3 New Connections to a Three-phase Overhead Line

Where the point of connection for a single-phase compact substation is via a pole termination onto a three-phase overhead line all three phases of the cable shall be connected to the overhead line. At the substation the unused phase shall be connected to the ‘spare’ centre bushing as described in Section 6.2.2.

6.2.4 New Connections to a Single-phase Overhead Line

Where the point of connection for a single-phase compact substation is onto a single-phase overhead line a standard three-phase pole termination shall be used; the two phases of the cable connected to the ‘A1’ and ‘A8’ terminals of the compact substation shall be connected to the overhead line and the third unused phase shall be connected to earth at the pole termination.

At the substation the unused phase shall be connected to the ‘spare’ centre bushing as described in Section 6.2.2

6.2.5 Work on Circuits Containing Spare Cores

The unused core of a cable is an integral part of the HV cable and any work or testing on the cable or its terminations shall be carried out in accordance with the Distribution Safety Rules.

6.2.6 Existing Networks

Where existing compact substations are found to have been connected using a different method to those described above, they should be modified during any works that involve a significant alteration to any section of underground cable; for example replacement of poles or plant at the cable terminations or the addition of more underground cable to the section.
Note: Some single-phase compact substations in the EPN area were not supplied with a spare bushing for termination of the third core. At these sites the third core should have been pot ended just outside the substation. However, at some sites this may not be the case and only a heat-shrink cap may have been used. Therefore, care shall be taken to establish, by excavation, that the third core has been correctly pot ended.

6.3 Earthing

6.3.1 Substation Earthing System

An earthing study shall be carried out for all compact substations in accordance with EDS 06-0014 and an earthing construction form and drawing provided detailing the required substation earthing system. The earthing shall be installed in accordance with ECS 06-0023.

The earthing form will also specify whether the HV and LV earths are to be combined or separated. Refer to Sections 6.3.2 and 6.3.3 for details of how to combine and separate the HV/LV earths in different sizes of compact substation.

6.3.2 HV and LV Earths in 50kVA and 100kVA Compact Substations

Compact substations up to and including 100kVA are supplied with the HV and LV earth connection separated. An LV neutral/earth connection and a separate HV earth busbar located in the LV compartment are provided (Figure 6-2). A label inside the LV door states ‘Separate HV and LV earths’ (refer to Section 8 on labelling).

If a combined HV/LV earth is specified the LV and HV earths shall be connected with a length of 70mm² copper earth cable and the warning label for separate earths shall be removed.

6.3.3 HV and LV Earths in 200kVA and 315kVA Compact Substations

As standard the 200kVA and 315kVA compact substations are supplied with the HV and LV earth terminals connected (Figure 6-3).

If a separate HV/LV earth is specified the dedicated earth link or the flexible earth lead between the LV neutral/earth bar and the HV steelwork earth shall be removed. The LV earthing shall then be connected to the LV neutral/earth bar and the HV earth to the HV earthing connection (steelwork earth). If the earths are separated a warning label denoting that the HV and LV earths are separated shall be fitted inside the left-hand door.
Figure 6-2 – 50/100kVA Earthing Arrangement

Figure 6-3 – 200/315kVA 50kVA and 100kVA
6.4 HOT Sites

Install the earthing in accordance with Section 6.3 and labelling in accordance with Section 7.

The 13A socket in 200kVA and 300kVA compact substations shall be disabled as follows:

- Lock off the RCBO and apply a warning label as shown in Figure 6-4.
- Apply a warning label to the socket as shown in Figure 6-5.

Additionally if the compact is installed in a GRP enclosure the power and lighting shall not be installed.

Figure 6-4 – Compact Substation RCBO

Figure 6-5 – Compact Substation Socket
7 Labelling

7.1 Circuit Labelling

The incoming and outgoing circuit distributor ways shall be clearly labelled.

7.2 Statutory Safety Notices and Equipment Labels

7.2.1 External Danger of Death Safety Notice

The compact substation is supplied with the statutory Danger of Death safety notice and a standard identification label fitted to the outside of the right-hand door.

7.2.2 HV Labels

The safety label on the cover of the HV cable box is shown in Figure 7-1 and the separable connector securing plate in Figure 7-2.

A tap changer operation label is provided adjacent to the tap changer handle (Figure 8-7 and Figure 8-9).

7.2.3 LV Label

Above the LV fuse way on compact substations up to and including 100kVA a label is fitted as shown in Figure 7-3.
7.2.4 Earth Label

Compact substations up to and including 100kVA are supplied with separate HV and LV earths (as per Section 6.3.2) and the label shown in Figure 7-4. If the HV and LV earths are combined the label shall be removed.

On 200kVA and 315kVA compact substations the label shown in Figure 7-4 shall be fitted if the HV and LV earths are separated (refer to ECS 06-0023).

7.2.5 Operational Label

The ‘Wear HV Gloves’ label shown in Figure 7-5 shall be fitted to the inside of all compact substations.

![Separate HV and LV earths](image1)

![Wear HV Gloves to operate](image2)

Figure 7-4 – Separate Earth Label  
Figure 7-5 – Wear HV Gloves Label

7.3 Identification Labels

The rating plate and connections diagram are provided on the inside of the left hand door. There is also an identification plate on the outside above the door.
8 Operation

8.1 General

The operation of compact substations shall be in accordance with the UK Power Networks Distribution Safety Rules.

8.2 HV Cable Access and Disconnection

8.2.1 Overview

The HV cable terminations are either held in place with standard bolted connections within an integral HV cable box (Figure 8-1) or using separable connectors and a securing plate (Figure 8-2).

Prior to opening the HV cable box or removing the securing plate a safety document shall be issued in accordance DSR 01 002. An overview of the procedure for identifying the cable at the point of work is given in Section 8.2.2.

8.2.2 Cable Identification at the Point of Work

Before working on the HV cable it is necessary to prove the HV terminations are not LIVE.

1. Confirm HV cable is isolated and identify the point of work using one of the following methods:
   - Monitoring transformer hum and checking LV voltage in accordance with DSR 01 015 8.1.2 and 8.1.1.
   - Using an approved testing device\(^1\) in accordance with DSR 01 015 8.1.2.
   - Signal injection in accordance with DSR 01 007.
   - Spiking the cable below the terminations in accordance with DSR 01 007.

2. Issue a safety document in accordance with DSR 01 002 8.16.2 and DSR 01 013.

3. Open the HV cable box and disconnect the HV cable in accordance with the 11kV Jointing manual or disconnect the separable connectors as detailed in Section 8.2.3 below.

\(^1\) An approved testing device with the appropriate detection range for the capacitive bushings is not currently available. This document will be updated when one becomes available.
8.2.3 Separable Connector Disconnection

1. Ensure a safety document has been issued in accordance with DSR 01 013.

2. Remove the securing plate (Figure 8-3 and Figure 8-4).

3. Remove clamps that hold the separable connector in place (Figure 8-4).

4. Disconnect HV cables by pulling separable connector towards you (Figure 8-5).

5. Fit protector caps to bushings (Figure 8-6).

6. Disconnect cable screen and drain earths.
8.3 Tap Changer

8.3.1 Voltage Levels

The compact substation is available with a nominal primary voltage of 11kV, 6.6kV or 3.5kV. All transformers are equipped with a five position off-load HV tap changer operating in the ranges of +5%, +2.5%, Nominal, -2.5%, and -5%.

8.3.2 Tap Changer Operation

The tap changer shall not be operated when the compact is energised. In order to operate the tap changer when the compact is in service, the procedure detailed in Section 8.2 shall be followed and a safety document issued.

On new 50kVA and 100kVA compact substations the control for the tap changer is located above the HV cable connections (Figure 8-7 and Figure 8-8).

On new 200kVA and 315kVA compact substations the control for the tap changer is situated between the HV cable box and the LV fuse unit (Figure 8-9).

The tap changer control on all units shall be locked after use. The only exception is on legacy units where the tap change control is located inside the HV cable box and the lock would interfere with the HV insulation.

To change the tap, the tap switch shall be pulled outwards sharply, rotated to the correct tap position, and pushed in, checking that the guides on the switch correctly locate on either side of the position indicator tag. Operating instructions can be found on a label (Figure 8-10) adjacent to the tap changer.
8.4 Protection

8.4.1 50kVA and 100kVA Compact Substations

8.4.1.1 HV Fusing

The HV protection is provided by HV full range fuses fitted under oil in the transformer tank.

The replacement of the HV fusing can only be carried out by qualified staff in a workshop environment following a full test of the transformer winding.

If the fuses have operated, this may be detected by testing for continuity between the HV terminals.

No attempt shall be made to investigate or replace a suspected blown fuse on site. A replacement compact substation shall be installed. The failed compact substation shall be returned to stores for investigation if it is less than five years old.

8.4.1.2 LV Fusing

Compact substations up to and including 100kVA contain a single set of LV standard J type fuses for connection to a LV cable up to 300mm² Waveform. This takes the form of a 300A single pole heavy-duty cut-out on each phase of the transformer.

The maximum fuse ratings are shown on a label in the LV compartment. These are designed to grade with the HV fuses. To avoid blowing the HV fuse due to the through passage of fault current the LV fusing is strictly limited to the maximum size indicated on the label. Similarly the use of ‘Rezap’ is strictly limited to settings below the maximum LV fuse size indicated.

There are no LV transformer links. For isolating the outgoing cables the fuses shall be removed. For isolating the neutral, the flexible connection from the bushing to the neutral busbar shall be disconnected, either from the neutral connection stem or from the neutral bushing. The LV bushing cover will need to be removed to gain access.

8.4.2 200kVA and 315kVA Compact Substations

8.4.2.1 HV Fusing

200kVA and 315kVA compact substations incorporate a two fuse protection system. The transformer is protected by a current limiting back up fuse and a Bay-O-Net current sensing fuse. This arrangement allows secondary faults and over-currents to be cleared by the Bay-O-Net fuse, and high level faults in the winding to be cleared by the current limiting fuse.

The two fuses are connected in series, and are co-ordinated so that the current-limiting fuse operates only upon internal equipment failure, in which case both the current-limiting and the Bay-O-Net fuse will operate.

The replacement of the Bay-O-Net fuse can be carried out on site in accordance with the Distribution Safety Rules. The Bay-O-Net fuses are situated behind a labelled metal cover and are accessible once the front doors are opened and the cover removed, as shown in Figure 8-11.
Note: Before the Bay-O-Net Fuse is unclipped and removed it is important to relieve any pressure built up in the transformer tank. This is achieved by gripping the dome of the pressure relief valve and gently pulling it towards you, air will be heard to escape. Failure to carry out this procedure may result in oil being discharged from the fuse holder.

![Figure 8-11 -- HV Bay-O-Net Fuses](image)

If the Bay-O-Net fuses are to be removed for a period greater than one hour then the fuse link shall be removed from the withdrawable fuse holder and stored in the HV cable box. The withdrawable fuse carriers shall then be repositioned in their holders.

The replacement of the current limiting fuse can only be carried out by qualified staff in a workshop environment following a full test of the transformer winding. If fuses have operated, this may be detected by testing for continuity between the HV terminals.

No attempt is to be made to investigate or replace a suspected blown current limiting fuse on site. If this situation arises then normally a replacement substation is to be installed. The failed compact substation shall be returned to stores for investigation if it is less than five years old.

8.4.2.2 LV Fusing

200kVA and 315kVA compact substations have an LV panel with up to three outgoing ways and a set of transformer links.

To avoid blowing the HV fuse due to the through passage of fault current the LV fusing shall be strictly limited to the maximum size detailed in EDS 05-4001. Similarly the use of ‘Rezap’ is strictly limited to settings below the maximum LV fuse size indicated.

8.4.3 HV and LV Fuse Sizes

Refer to EDS 05-4001 for a full list of HV Bay-O-Net and LV fuse ratings.
9  Documentation

The manufacturer’s installation, operation and maintenance manual, general arrangement drawings and rating plates is available from:


10  References

10.1  UK Power Networks’ Standards

Distribution Safety Rules
DSR 01 002  HV Systems Operations
DSR 01 007  Identification of High Voltage Cables
DSR 01 013  Safety Documents
DSR 01 015  Identification of Points of Work
ECS 02-0011  11kV Jointing Manual
EAS 00-0004  Distribution Transformer Material List
EDS 05-4001  Fuse Ratings at Distribution Substations’
ECS 06-0023  Secondary Distribution Network Earthing Construction
EAS 07-0021  Signs and Labels for Operational Sites
EDS 07-3102  Secondary Substation Civil Designs
EDS 08-3000  HV Network Design
LV Jointing Manual

10.2  Other Documents

CG Power Systems Compact Substation IOM Manual
Appendix A – Typical General Arrangement Drawings

General arrangement drawings for the complete range of compact substations can be found in the Reference Library (see Section 8.4). Examples for a 50kVA single-phase and a 315kVA three-phase unit are shown on the following pages.