WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

Company Directive

POLICY DOCUMENT: SD4/9

Relating to 11kV and 6.6kV Network Design

Policy Summary
This document describes the requirements for the design of 11kV and 6.6kV networks.

Author: **Andy Hood**

Implementation Date: **May 2020**

Approved by

Nigel Turvey

Nigel Turvey
DSO & Future Networks Manager

Date: **26th May 2020**

Target Staff Group	**Staff involved with the analysis, design, construction, maintenance and replacement of Western Power Distribution's network**
Impact of Change	**Amber – This document modifies the requirements for 11kV and 6.6kV network design, including for Network Integrity, System Integrity and Load Management Schemes**
Planned Assurance checks	**12 months from the issue of this document the author will interview at least one 11kV Planner in each License Area and seek evidence of compliance with the new Network Integrity and System Integrity requirements**

NOTE: The current version of this document is stored in the WPD Corporate Information Database. Any other copy in electronic or printed format may be out of date.

IMPLEMENTATION PLAN

Introduction

POL: SD4 specifies the requirements for 11kV and 6.6kV network design.

Main Changes

The following significant changes have been included in this document:

- Definitions have been added
- New requirements for **Network Integrity** and **System Integrity**
- New requirements for **Step Voltage Changes**
- A reference to POL:SD11, Network Design Requirements for **Load Management Schemes**

Impact of Changes

Target Staff Group	**Staff involved with the analysis, design, construction, maintenance and replacement of Western Power Distribution's network**
Impact of Change	**Amber – This document modifies the requirements for 11kV and 6.6kV network design including for Network Integrity, System Integrity and Load Management Schemes**

Implementation Actions

Managers shall ensure that all relevant staff are familiar with and follow the requirements of this document.

Implementation Timescale

Document is implemented on issue for new and significantly modified 11kV and 6.6kV networks.

REVISION HISTORY

Document Revision and Review Table		
Date	Comments	Name
October 2020	• Note 6 and 7 in Table 1 amended	Andy Hood
May 2020	• Document has been re-formatted to comply with POL:GE1 • Definitions have been added. • References to the Electricity Safety Quality and Continuity Regulations and to the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) have been added. • **Generation Security**, **Network Integrity**, **System Integrity** requirements have been added • Network complexity requirements have been clarified. • **Load Management Scheme** requirements have been modified. • **Step Voltage Change** requirements have been modified. • A section on network losses has been added.	Andy Hood
December 2019	• Page 5, Section 2.1.2 - ST:AM5C removed and replaced with POL:AM5.	Andy Hood
September 2018	• A reference to EREC G99 has been added to Section 2.3 and Appendix B.	Andy Hood
September 2017	• Section 2.1.1 relating to the requirements for networks that include active load management has been added.	Andy Hood

Contents

1.0 INTRODUCTION

1.1 This document describes the standard requirements for the design of the 11kV and 6.6kV network including for **Demand Security**, **Generation Security**, **Network Integrity**, **System Integrity**, supply quality, safety, network losses, asset utilisation and capital investment requirements. Where any difficulty is encountered with the application of this policy, the author should be notified, who will consider if a variation to this policy is appropriate.

2.0 DEFINITIONS

2.1 **Demand Security**: The ability to meet customer demand under Intact Network and outage conditions.

2.2 **Generation Security**: The ability to accept customer export under **Intact Network** and outage conditions.

2.3 **Intact Network**: A network operating with open points in their normal position and without any outages that are material to the condition being considered or studied. The **Intact Network** arrangement shall be agreed between Network Strategy, Operations Support, Control and Network Services and indicated on network diagrams and control systems.

2.4 **Load:** The apparent power (e.g. kVA or MVA) associated demand and/or generation.

2.5 **Load Management Schemes**: Plant, equipment and software systems that together manage network loading and voltages by either controlling demand and/or generation connected to the network, operating switchgear to change the topology of the network and/or controlling the settings of tap-change controllers, reactive compensation equipment and flexible power links.

Examples of **Load Management Schemes** include but are not limited to:

- Operational Intertripping
- Active Network Management (ANM)
- Soft-intertripping
- Timed connections
- Overload protection
- Auto-changeover
- Voltage constraint systems
- Remote control of switchgear or other plant and equipment

The following are outside of the scope of this definition:

- Customer-owned export limitation schemes
- Conventional independent tap-change control schemes
- Network protection for fault clearance
- Loss-of-mains protection, including loss-of-mains intertripping

2.6 **Network Integrity**: The ability of a network to operate within thermal, voltage and other technical limits, excluding frequency-related limits, under both **Intact Network** and outage conditions.

2.7 **Operational Secured Next Fault:** A fault outage after which **Demand Security, Generation Security, Network Integrity** and **System Integrity** requirements must be satisfied when operating the network.

The following fault conditions starting from the prevailing running arrangement are considered:

- Each circuit fault
- Each busbar fault

Outages at all voltage levels relevant to the network in question shall be considered, including outages on the transmission system and other third party networks, where applicable.

2.8 **Secured Outage**: An outage or combination of outages after which **Demand Security, Generation Security, Network Integrity** and **System Integrity** requirements must be satisfied in design studies.

The following types and combinations of outages are considered when 11kV and 6.6kV networks are designed:

- Each circuit fault outage*
- Each busbar fault outage
- Each circuit arranged outage*
- Each circuit arranged outage followed by each circuit fault outage*
- Each circuit arranged outage followed by each busbar fault outage
- Each busbar arranged outage*
- Each busbar arranged outage followed by each circuit fault outage*
- Each busbar arranged outage followed by each busbar fault outage

Outages at all voltage levels relevant to the network in question shall be considered, so far as is possible, including outages on the transmission network and other third-party networks where applicable.

Network Integrity and **System Integrity** requirements apply to all **Secured Outages**.

Demand Security and **Generation Security** requirements are set by EREC P2, bilateral agreements with customers, consideration of CIs and CMLs and consideration of vulnerable customer obligations, in accordance with Section 3.1. They may only apply for a subset of **Secured Outages**. The outage types and combinations with **Demand Security** requirements in EREC P2 are marked with asterisks (*) above.

2.9 **Step Voltage Change:** The change from the initial voltage level to the resulting voltage level after all generating unit automatic voltage regulator (AVR) and static var compensator (SVC) actions and transient decay (typically 5s after the fault clearance or system switching) have taken place, but before any other automatic or manual tap-changing and switching actions have commenced.

The percentage **Step Voltage Change** is the value of **Step Voltage Change** in volts expressed as percentage change of the nominal system voltage.

2.10 **System Integrity**: The ability of the GB system to operate within acceptable frequency-related technical limits under both **Intact Network** and outage conditions.

System Integrity is primarily managed by National Grid, but it can be affected by the operation of WPD's network and customers. This includes but is not limited to:

- Low Frequency Demand Disconnection
- Generator Interface Protection
- Changes in net **Load** caused by protection operation, manual intervention or the operation of **Load Management Schemes**.

2.11 **Unsecured Outage:** An outage condition that is beyond the scope of a **Secured Outage**.

Unsecured Outages are not normally considered when designing the network. Examples include:

- Multiple concurrent arranged outages
- Circuit breaker failure fault outages
- Multiple concurrent fault outages
- The concurrent fault outage of multiple circuits sharing the same structure, such as double circuit tower lines

3.0 POLICY

The design of the 11kV and 6.6kV network shall satisfy the requirements of the Electricity Safety, Quality and Continuity Regulations, Distribution Code of Licensed Distribution Network Operators of Great Britain and the relevant requirements of the Grid Code and the National Electricity Transmission System Security and Quality of Supply Standard.

3.1 Security

11kV and 6.6kV networks shall be designed to satisfy the **Demand Security** requirements and **Generation Security** requirements specified in:

- EREC P2 for **Demand Security**
- bilateral connection agreements with customers and other network operators for both **Demand Security** and **Generation Security**

Due consideration shall also be given to Customer Interruptions (CIs), Customer Minutes Lost (CMLs) and to vulnerable customer obligations. In addition, no more than 5000 customers shall be fed from a single 66kV or single 33kV transformer unless there is an automatic or remotely operable back-feed arrangement.

3.2 Network Integrity

11kV and 6.6kV networks shall be designed to enable **Network Integrity** to be maintained under **Intact Network** conditions, **Secured Outage** conditions and for **Operational Secured Next Faults**. **Network Integrity** may be maintained by the inherent capability of the plant and equipment, operation of protection, operation of **Load Management Schemes** or by manual intervention.

11kV and 6.6kV networks shall be designed to allow Control Engineers and Outage Planning Engineers to maintain Network Integrity for **Operational Secured Next Faults**, even where these go beyond the requirements of Secured Outages.

3.3 System Integrity

11kV and 6.6kV networks shall be designed to enable **System Integrity** to be maintained under **Intact Network** conditions and **Operational Secured Next Fault** conditions for **Operational Secured Next Faults** and for credible step changes in **Load**. In this context, the change of **Load** across all license areas and all voltage levels shall not exceed 300MW unless explicitly agreed with National Grid.

3.4 Load Management Systems

Where the **Load** is actively managed the network and the associated **Load Management Scheme** shall satisfy the requirements of POL:SD11.

3.5 Network Improvements

Improvements to **Demand Security**, **Generation Security**, **Network Integrity**, **System Security** and network complexity will be considered in accordance with POL:AM5.

3.6 Supply Quality

11kV and 6.6kV networks shall be designed to:

- have a voltage regulation that will ensure that the voltage at customer connection points, including low voltage connection points comply with the limits in the Electricity Safety, Quality and Continuity Regulations. Further guidance is provided in Section 4.1

- ensure that customer connections comply with the voltage unbalance limits contained in EREC P29

- ensure that customer connections comply with the voltage fluctuation requirements of EREC P28. Clause 6.2 of EREC P28 allows Distribution Network Operators some discretion with regard to **Step Voltage Change** limits caused by customer equipment and installations. Western Power Distribution's **Step Voltage Change** limits applicable to customer connections are defined in Table 1.

- ensure that customer connections comply with the limits for harmonics in the UK contained in EREC G5

- have a **Step Voltage Change** no higher than the limits specified in Table 2 for Distribution Network Operator, Independent Distribution Network Operator and Transmission Network Operator events and operations.

Condition[3]	**Step Voltage Change Limit**[1,2]
Import / Export Variation	-3% fall and +3% rise subject to compliance with P28 flicker limits[4]
Load Management Scheme curtailment	-3% fall and +3% rise subject to compliance with P28 flicker limits
Generator interface (e.g. G59 or G99) protection trip	-6% fall and +6% rise
Fast frequency response (e.g. maximum import to maximum export and vice versa)	-3% fall and +3% rise
Frequent[5] operational switching by the customer	-3% fall and +3% rise subject to compliance with P28 flicker limits
Infrequent[6] operational switching by the customer	-3% fall and +3% rise
Very Infrequent[7] operational switching by the customer	-6% fall and +6% rise
Note 1: *Limits apply at the point of common coupling*	
Note 2: *Limits are expressed as percentage of nominal system voltage. For example, for an 11kV network a 3%* ***Step Voltage Change*** *equates to a voltage change of 330V phase-phase.*	
Note 3: *Consider the most onerous operating arrangements specified in P28 and the most onerous demand / generation conditions (e.g. max. demand and min. generation / min. demand and max. generation).*	
Note 4: *For the purpose of this assessment wind turbine and photovoltaic* ***Generating Units*** *are assumed to have a minimum output of 20% of their maximum capacity. Other types of* ***Generating Units*** *are assumed to have a zero minimum output.*	
Note 5*: Frequent operational switching events are those that are expected to occur more than 4 times in any month, consist of more than 4 operations in any day or include operations that are separated by less than 10 minutes.*	
Note 6: *Infrequent operational switching events occur more frequently than once every three months up to a maximum of 4 times in a calendar month. Each event may consist of up to 4 operations in one day, each operation separated by at least 10 minutes.*	
Note 7: *Very infrequent operational switching events occur no more frequently than once every 3 months. Each event may consist of up to 4 operations in one day, each separated by at least 10 minutes.*	

Table 1 Step Voltage Change Limits associated with Customer Equipment and Connections

Condition	Step Voltage Change Limit[8,9]
Trip metering circuit breaker	-6% fall and +6% rise
Secured Outage[10]	-6%[11] fall and +6%
Specific secured events[12]	-12% fall and +6% rise
Load Management Scheme communication system or IT system disconnection or failure	-10% fall and +6% rise
Fast Frequency Response event	-6% fall and +6% rise
Frequent[13] operational switching	-3% fall and +3% rise
Infrequent[14] operational switching	-6% fall and +6% rise
Note 8: *Limits apply at customer Connection Points and at the lower voltage busbar of Bulk Supply Points.*	
Note 9: *Limits are expressed as percentage of nominal system voltage. For example, for 132kV* ***Connection Points*** *a 3%* ***Step Voltage Change*** *equates to a voltage change of 3.96kV phase-phase.*	
Note 10: *See the definition for* ***Secured Outage.***	
Note 11: *If the -6% limit is exceeded then values up to -10% may be considered as long as this is supported by an appropriate cost benefit analysis that is approved by the Primary System Design Manager.*	
Note 12: *Events specified within section b) and c) of Table 6.5 of the National Electricity Transmission System Security and Quality of Supply Standard (SQCC)*	
Note 13: *Operational switching events that are expected to occur several times per day, including automatic operation of tap-changers etc.*	
Note 14*: Operational switching events that are expected to occur less than once per day on average associated with plant/equipment commissioning and maintenance etc.*	

Table 2 Step Voltage Change Limits for Network Operations, Outages and Events

3.7 Safety

11kV and 6.6kV networks shall:

- be protected in accordance with POL:TP4
- comply with EREC G59 or EREC G99, as applicable
- take account of the fault level calculation methodology detailed in EREC G74
- operate within equipment design ratings including any appropriate cyclic or short term rating as defined in appropriate Engineering Instructions and Directives.

3.8 **Losses**

Western Power Distribution is obliged to operate an efficient and economic system through the Distribution Licence. Standard Licence Condition 49 requires WPD ensure distribution losses are as low as reasonably practicable, to maintain a Losses Strategy and to design, build and operate the network in a manner that is reasonably expected to ensure losses are as low as reasonably practicable.

11kV and 6.6kV Networks shall be designed in accordance with ST:SD1H, The Treatment of Losses in an Inclusive Network Design Process

3.9 **Asset Utilisation and Capital Investment**

11kV and 6.6kV networks will be designed:

- using short circuit and load flow analysis tools approved by the Network Strategy Manager.
- using equipment of standard capacities.
- to improve asset utilisation whilst meeting the **Demand Security**, **Generation Security**, **Network Integrity**, **System Integrity**, supply quality, safety and network loss requirements specified in this document.
- for the lowest lifetime cost in accordance with POL:AM5
- to ensure correct operation in parallel with other Network Operator systems.

4.0 BACKGROUND INFORMATION

4.1 **Voltage Limits**

4.1.1 WPD's distribution transformers generally have manually adjustable (rather than automatically adjustable) tap positions. This means that the voltage on the LV network is controlled by the automatic tap-changers and automatic voltage regulators on the 11kV and 6.6kV networks.

4.1.2 It is assumed that the maximum voltage regulation across the LV network and distribution transformer is +1.5% and - 8% of nominal voltage. This equates to a maximum voltage rise of +3.45V on the LV network (including the voltage rise across the distribution transformer) and maximum voltage drop of 18.4V on the LV network (including the voltage drop across the distribution transformer).

4.1.3 In order to maintain statutory voltage at LV, 11kV and 6.6kV connections the maximum and minimum voltage limits defined in Table 3 and Table 4 shall be satisfied. These tables specify the voltage limits at the HV terminals of WPD owned distribution transformers, and at HV connected customers. The limits at the HV terminals of a distribution transformer depend on the transformer tap position.

4.1.4 Lower voltage limits for back feed conditions are listed in brackets, e.g. (9.77kV) for an 11kV transformer on the 0% tap. Despite this, all reasonable steps shall be taken to satisfy the normal voltage limits when outages are taken, for example by:

- Only taking planned outages during periods of low load.
- Splitting the back fed network between different circuits.
- Feeding some substations from mobile generators.

Where it is not possible to satisfy the normal limits during back feed conditions the lower limits may be used, however the duration shall be kept to a minimum.

These steps will minimise the risk of a network running outside of statutory limits whilst still allowing the network to be back fed under the most extreme conditions.

4.1.5 In addition to the above requirements, the RMS voltage on any part of WPD's 11kV network shall not exceed 12kV and on any part of WPD's 6.6kV network shall not exceed 7.2kV, in order to ensure equipment ratings are not exceeded.

4.1.6 When assessing the maximum voltage rise and maximum voltage drop on the network the bandwidth of tap change control schemes shall be taken into account. This bandwidth is specified by Engineering Design and depends on the size of the tap steps, the make and type of tap-change control relay (e.g. electromechanical or electronic / solid state) and, to some extent, on the characteristics of the load. The bandwidth is set between +/- 1.0% and +/- 2.0% and a value of +/-1.25% is typical. Consideration shall also be given to line/load drop compensation settings, where applied.

4.1.7 The value of voltage drop / rise across 11kV/LV or 6.6kV/LV distribution transformer depends on the magnitude of current flowing through the transformer and the power factor. Table 5 lists the voltage drop across different types of distribution transformers operating at their name plate rating (based on a phase to neutral voltage of 230V) for a number of different power factors.

<table>
<tr><th rowspan="2">Distribution Transformer Tap (%)</th><th colspan="2">Voltage Limits for the HV terminals of WPD 11kV Distribution Transformers</th><th colspan="2">Voltage Limits for HV Metered Connections</th></tr>
<tr><th>Max.[2]</th><th>Min.</th><th>Max.[2]</th><th>Min.</th></tr>
<tr><td>+5%</td><td>11.59kV</td><td>10.68kV
(10.25kV)[1]</td><td rowspan="5">11.66kV</td><td rowspan="5">10.34kV
(9.90kV)[1]</td></tr>
<tr><td>+2.5%</td><td>11.31kV</td><td>10.42kV
(10.01kV)[1]</td></tr>
<tr><td>0</td><td>11.04kV</td><td>10.17kV
(9.77kV)[1]</td></tr>
<tr><td>-2.5%</td><td>10.76kV</td><td>9.92kV
(9.52kV)[1]</td></tr>
<tr><td>-5%</td><td>10.49kV</td><td>9.66kV
(9.28kV)[1]</td></tr>
<tr><td colspan="5">Note 1: The values in brackets only apply under <u>abnormal</u> feeding arrangements. Further guidance on the application of these limits is given in 3.1.4.</td></tr>
<tr><td colspan="5">Note 2: The maximum values apply under both normal and abnormal feeding arrangements.</td></tr>
<tr><td colspan="5">Note 3: Under no circumstances shall the RMS voltage on the 11kV network exceed 12kV.</td></tr>
</table>

Table 3 Voltage Limits on the 11kV Network[3]

Distribution Transformer Tap (%)	Voltage Limits for the HV terminals of WPD 6.6kV Distribution Transformers		Voltage Limits for HV Metered Connections	
	Max.[2]	**Min.**	**Max.**[2]	**Min.**
+8.4%[4]	7.00kV	6.61kV (6.35kV)[1]	7.00kV	6.20kV (5.94kV)[1]
+5%[4]	6.95kV	6.41kV (6.15kV)[1]		
+4.2%[4]	6.90kV	6.36kV (6.10kV)[1]		
+2.5%[4]	6.79kV	6.25kV (6.01kV)[1]		
0	6.62kV	6.10kV (5.86kV)[1]		
-2.5%[4]	6.46kV	5.95kV (5.71kV)[1]		
-4.2%[4]	6.35kV	5.85kV (5.62kV)[1]		
-5%[4]	6.29kV	5.80kV (5.57kV)[1]		
-8.4%[4]	6.07kV	5.59kV (5.37kV)[1]		
Note 1: *The values in brackets only apply under abnormal feeding arrangements. Further guidance on the application of these limits is given in 3.1.4.*				
Note 2: *The maximum values apply under both normal and abnormal feeding arrangements.*				
Note 3*: Under no circumstances shall the RMS voltage on the 6.6kV network exceed 7.2kV.*				
Note 4: *11000/6600/433V dual ratio transformers either have 2.5% tap steps or 4.2% tap steps when connected to their 6600/433 ratio. Please refer to the transformer name-plate for the available tap steps.*				

Table 4 Voltage Limits on the 6.6kV Network[3]

T/F Type/Rating	R(Ω)	X(Ω)	Current (A)	Percentage Voltage Change (230V base)[1]										
					Lagging Power Factor						Leading Power factor[2]			
				1.00	0.99	0.98	0.95	0.90	0.85	0.80	0.99	0.98	0.95	0.9
Conventional Ground Mounted Transformers														
1500 kVA 3Ø	0.0013	0.0067	2000.00	1.13%	1.94%	2.27%	2.89%	3.56%	4.03%	4.40%	0.30%	-0.05%	-0.75%	-1.52%
1000 kVA 3Ø	0.0022	0.0086	1333.33	1.28%	1.97%	2.24%	2.77%	3.32%	3.71%	4.01%	0.56%	0.26%	-0.35%	-1.03%
800 kVA 3Ø	0.0029	0.0107	1066.67	1.34%	2.03%	2.31%	2.83%	3.37%	3.76%	4.05%	0.63%	0.33%	-0.27%	-0.95%
750 kVA 3Ø	0.0031	0.0115	1000.00	1.35%	2.04%	2.32%	2.84%	3.39%	3.39%	4.08%	0.63%	0.33%	-0.28%	-0.97%
500 kVA 3Ø	0.0051	0.0171	666.67	1.48%	2.16%	2.44%	2.95%	3.49%	3.49%	4.16%	0.76%	0.46%	-0.14%	-0.83%
315 kVA 3Ø	0.0090	0.0268	420.00	1.64%	2.32%	2.58%	3.09%	3.61%	3.61%	4.25%	0.94%	0.64%	0.03%	-0.65%
300 kVA 3Ø	0.0095	0.0277	400.00	1.65%	2.32%	2.58%	3.07%	3.59%	3.59%	4.21%	0.96%	0.66%	0.07%	-0.61%
200 kVA 3Ø	0.0158	0.0406	266.67	1.83%	2.48%	2.73%	3.21%	3.70%	3.70%	4.29%	1.15%	0.86%	0.27%	-0.40%
Pole Mounted Transformers														
315 kVA 3Ø	0.0090	0.0268	420.00	1.64%	2.32%	2.58%	3.09%	3.61%	3.97%	4.25%	0.94%	0.64%	0.03%	-0.65%
200 kVA 3Ø	0.0158	0.0406	266.67	1.83%	2.48%	2.73%	3.21%	3.70%	4.04%	4.29%	1.15%	0.86%	0.27%	-0.40%
100 kVA 3Ø	0.0371	0.0810	133.33	2.15%	2.79%	3.04%	3.51%	3.98%	4.30%	4.54%	1.47%	1.17%	0.58%	-0.11%
50 kVA 3Ø	0.0876	0.1440	66.67	2.54%	3.10%	3.32%	3.72%	4.10%	4.36%	4.54%	1.92%	1.66%	1.11%	0.47%
25 kVA 3Ø	0.2080	0.2660	33.33	3.01%	3.53%	3.72%	4.07%	4.39%	4.59%	4.72%	2.44%	2.19%	1.66%	1.03%
100 kVA Split Phase	0.0223	0.0510	200.00	1.93%	2.54%	2.78%	3.22%	3.67%	3.98%	4.21%	1.29%	1.10%	0.45%	-0.19%
50 kVA Split Phase	0.0532	0.0992	100.00	2.31%	2.90%	3.13%	3.54%	3.96%	4.24%	4.44%	1.68%	1.41%	0.85%	0.20%
25 kVA Split Phase	0.1124	0.1888	50.00	2.44%	3.00%	3.21%	3.60%	3.99%	4.24%	4.42%	1.84%	1.58%	1.04%	0.41%
100 kVA 1Ø	0.0111	0.0255	400.00	1.93%	2.54%	2.78%	3.22%	3.67%	3.98%	4.21%	1.29%	1.01%	0.45%	-0.19%
50 kVA 1Ø	0.0266	0.0496	200.00	2.31%	2.90%	3.13%	3.54%	3.96%	4.24%	4.44%	1.68%	1.41%	0.85%	0.20%
25 kVA 1Ø	0.0612	0.0944	100.00	2.66%	3.21%	3.42%	3.81%	4.18%	5.42%	4.59%	2.06%	1.79%	1.25%	0.61%
16 kVA 1Ø	0.1390	0.1390	64.00	3.87%	4.37%	4.56%	4.88%	5.17%	5.33%	5.41%	3.28%	3.02%	2.47%	1.80%
15 kVA 1Ø	0.1460	0.1460	60.00	3.81%	4.31%	4.49%	4.81%	5.09%	5.24%	5.33%	3.23%	2.97%	2.43%	1.77%
10 kVA 1Ø	0.2060	0.2060	40.00	3.58%	4.05%	4.22%	4.52%	4.79%	4.93%	5.02%	3.04%	2.80%	2.28%	1.66%
5 kVA 1Ø	0.3620	0.3620	20.00	3.15%	3.56%	3.71%	3.97%	4.21%	4.33%	4.41%	2.67%	2.46%	2.01%	1.46%

Note 1: *Where active power (kW) flows in the conventional direction, i.e. from the HV side to the LV side of the transformer, positive values indicate voltage drop across the transformer and negative values (i.e. the shaded areas) indicate voltage rise. This convention is reversed where active power power flow is in the opposite direction.*

Note 2: *A demand customer with a leading power factor imports real power and exports reactive power. A Power Generating Facility with a leading power factor exports real power (kW) and imports reactive power (kVAR)*

Table 5: Voltage Drop / Rise across Distribution Transformers (% of 230V) at Rated Current

T/F Type/Rating	R(Ω)	X(Ω)	Current (A)	Percentage Voltage Change (230V base)[1]										
					Lagging Power Factor						Leading Power Factor[2]			
				1.00	0.99	0.98	0.95	0.90	0.85	0.80	0.99	0.98	0.95	0.9
Padmount Transformers														
200 kVA 3Ø (Coopers)	0.0074	0.0258	266.67	0.86%	1.27%	1.44%	1.75%	2.08%	2.31%	2.48%	0.43%	0.25%	-0.12%	-0.53%
100 kVA 3Ø (Coopers)	0.0271	0.0401	133.33	1.57%	1.88%	2.00%	2.22%	2.43%	2.56%	2.65%	1.23%	1.08%	0.77%	0.40%
50 kVA 1Ø (Coopers)	0.0182	0.0206	200.00	1.58%	1.82%	1.91%	2.06%	2.21%	2.29%	2.34%	1.31%	1.19%	0.94%	0.64%
315 kVA 3Ø (ABB)	0.0090	0.0268	420.00	1.64%	2.32%	2.58%	3.09%	3.61%	3.97%	4.25%	0.94%	0.64%	0.03%	-0.65%
200 kVA 3Ø (ABB)	0.0158	0.0406	266.67	1.83%	2.48%	2.73%	3.21%	3.70%	4.04%	4.29%	1.15%	0.86%	0.27%	-0.40%
100 kVA 3Ø (ABB)	0.0371	0.0810	133.33	2.15%	2.79%	3.04%	3.51%	3.98%	4.30%	4.54%	1.47%	1.17%	0.58%	-0.11%
50kVA 3Ø (ABB)	0.0876	0.1440	66.67	2.54%	3.10%	3.32%	3.72%	4.10%	4.36%	4.54%	1.92%	1.66%	1.11%	0.47%
50 kVA 1Ø (ABB)	0.0266	0.0496	200.00	2.31%	2.90%	3.13%	3.54%	3.96%	4.24%	4.44%	1.68%	1.41%	0.85%	0.20%
Note 1: *Where active power (kW) flows in the conventional direction, i.e. from the HV side to the LV side of the transformer, positive values indicate voltage drop across the transformer and negative values (i.e. the shaded areas) indicate voltage rise. This convention is reversed where active power power flow is in the opposite direction.*														
Note 2: *A demand customer with a leading power factor imports real power and exports reactive power. A Power Generating Facility with a leading power factor exports real power (kW) and imports reactive power (kVAR)*														

Table 5 (continued): Voltage Drop across Distribution Transformers (% of 230V) at Rated Current

4.2 General Background Information

The requirements of this policy have evolved over a period of time and represent tried and tested principles.

Engineering Directive POL:SD1 contains further information on the fundamental aims of network design.

APPENDIX A

SUPERSEDED DOCUMENTATION

This Document supersedes POL:SD4/8 dated September 2018 has now been withdrawn

APPENDIX B

RECORD OF COMMENT DURING CONSULTATION

POL: SD4/9 - Comments

APPENDIX C

ANCILLARY DOCUMENTATION

The Electricity Safety, Quality and Continuity Regulations

The Distribution Code of Licensed Distribution Network Operators of Great Britain

The Grid Code

National Electricity Transmission System Security and Quality of Supply Standard

EREC P2, Security of Supply

EREC P29, Planning limits for voltage unbalance in the United Kingdom

EREC P28, Voltage fluctuations and the connection of disturbing equipment to transmission systems and distribution networks in the United Kingdom

EREC G5, Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom

EREC G59, Recommendations for the connection of private generating plant to the distribution systems of Licensed Distribution Network Operators

EREC G99, Recommendations for the connection of generating equipment in parallel with public distribution networks on or after 27th April 2019

EREC G74, Procedure to meet the requirements of IEC 60909 for the calculation of short-circuit currents in three-phase AC power systems

POL: AM5, Technical Appraisal, Approval and Post Investment Appraisal for Network Relating Capital projects

APPENDIX D

KEY WORDS

11kV and 6.6kV, network, system, design, security, unbalance, fluctuation, harmonics, utilisation