WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

Company Directive

POLICY DOCUMENT: SD4/8

Relating to 11kV and 6.6kV System Design

Policy Summary

This document describes the standard requirements for the design of the 11kV and 6.6kV systems.

Reference is also made to the Distribution Code, ENA Engineering Recommendations P2 P28, P29, G5, G59, G99, G74 and to Western Power Distribution Engineering Directives POL:SD1 and POL:TP4 (as amended).

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Implementation Date: **September 2018**

Approved by Nigel Turvey

Network Strategy and Innovation Manager

Date: 12/9/2018

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 Any other copy in electronic or printed format may be out of date.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 high level requirements for 11kV and 6.6kV System Design.

Main Changes

References to ENA EREC G99 have been added

Impact of Changes

Power Generating Modules and Power Park Modules connected from 27th April 2019 shall comply with ENA EREC G99 unless the generator concluded a final and binding contract for the purchase of the main generating plant before 17th May 2018 and notified WPD of this by 17th November 2018.

Implementation Requirements

Managers shall ensure that staff involved in the design of the 11kV and/or 6.6kV network, or with the appraisal / approval of 11kV and/or 6.6kV capital sanctions, are aware of, and follow, the requirements of this document.

Implementation Timescale

Document implemented on issue.

REVISION HISTORY

Document Revision and Review Table		
Date	**Comments**	**Name**
September 2018	• A reference to ENA 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
February 2017	• The minimum voltage limits listed in Table 1 and Table 2 have been reduced by approximately 0.5%	Andy Hood
June 2015	• Point 3.1.2 on page 5 amended - voltage drop values corrected	Andy Hood
January 2015	• Table 2 has been expanded to include +8.4%, +4.2%, -4.2% and -8.4% tap positions that are provided on some dual ratio 11000/6600/433V transformers when set to their 6600V/433V ratio. • An additional footnote has been added to Table 3	Andy Hood

1.0 INTRODUCTION

This document describes the standard requirements for the design of the 11kV and 6.6kV systems and details the security, supply quality, safety, 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.

Where the term “load” is used within the document this refers to the load associated with both generation and demand.

The practical details of the application of this policy are contained in a range of ST documents with a reference beginning ST:SD4.

2.0 POLICY

The design of the 11kV and 6.6kV systems shall satisfy the requirements of the Distribution Code of Licensed of Distribution Network Operators of Great Britain, as amended.

2.1 System Security

11kV and 6.6kV systems shall be designed to:

- provide a standard of security not less than that set out in ENA EREC P2, as amended.
- have less than 5000 customers fed from single 66kV or single 33kV transformers, unless there is an automatic or remotely operable back-feed arrangement.

2.1.1 Where the load is actively managed, e.g. using Active Network Management (ANM), soft intertrip, conventional intertripping or other equivalent load constraint / control schemes, the network shall satisfy the following criteria:

(a) When the effect of active load management schemes are disregarded (i.e. the network is modelled without such schemes):

- The maximum load on any overhead circuit shall not exceed 110% of its rating
- The maximum load on any item of plant or equipment, excluding overhead lines, shall not exceed 125% of its rating
- The voltage on the 11kV and 6.6kV network shall remain within the following limits: Nominal Voltage +/- 10%

(b) Active load management systems shall, as far as possible, include watchdog and communications failure facilities that curtail the load in the event of a scheme failure. Such systems shall be designed to curtail the load before the thermal ratings of plant and equipment are exceeded.

(c) In the event of the failure of an active load management system or its associated communications / control systems, no more than 50MW of load shall be curtailed per minute and no more than 200MW of load shall be curtailed in total, across all voltage levels.

2.1.2 Improvements to system reliability will be considered in accordance with ST:AM5C and POL:FI 06/04/01.

2.2 Supply quality

11kV and 6.6kV systems will be designed:

- to ensure that the voltage at customers supply terminals comply with the limits defined in the Electricity Safety, Quality and Continuity Regulations 2002. Further guidance on maintaining voltage limits is provided in section 3.0.

- to ensure that new connections comply with the voltage unbalance limits contained in ENA EREC P29, as amended.

- to ensure that new connections comply with the voltage fluctuation requirements of ENA EREC P28, as amended.

- to ensure that new connections comply with the limits for harmonics in the UK contained in ENA EREC G5, as amended.

2.3 Safety

11kV and 6.6kV systems will be designed:

- to be protected in accordance with POL:TP4

- to comply with ENA EREC G59 or ENA EREC G99, as applicable

- to take account of the fault level calculation methodology as detailed in ENA EREC G74, as amended.

- to operate within equipment design ratings including any appropriate cyclic or short term rating as defined in the appropriate Engineering Instructions and Engineering Directives.

2.4 Asset Utilisation and Capital Investment

11kV and 6.6kV systems will be designed:

- using equipment approved by the Policy Manager.
- using equipment of standard capacities.
- to improve asset utilisation unless the system security, supply quality or safety criteria of this policy will be impaired.
- for the lowest lifetime cost in accordance with POL:AM5 and POL:FI 06/04/01.

3.0 BACKGROUND

3.1 Voltage Limits

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

3.1.2 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 + transformer and maximum voltage drop of 18.4V on the LV network + transformer.

3.1.3 In order to maintain statutory voltage at LV, 11kV and 6.6kV connections the maximum and minimum voltage limits defined in Table 1 and Table 2 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.

3.1.4 Lower voltage limits for back feed conditions are also listed in Table 1 and Table 2 (within brackets). 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.

3.1.5 In addition, in order to ensure equipment ratings are not exceeded, 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.

3.1.6 When assessing the maximum voltage rise and maximum voltage drop on the network the bandwidth of the tap change control scheme shall be taken into account. This bandwidth is specified by Primary System 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 drop (or load drop) compensation settings, where applied.

3.1.7 Distribution Transformer Voltage Regulation

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 3 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 1 Voltage Limits on the 11kV Network[3]

Distribution Transformer Tap (%)	Voltage Limits for the HV terminals of WPD 11kV Distribution Transformers		Voltage Limits for HV Metered Connections	
	Max.[2]	**Min.**	**Max.[2]**	**Min.**
+7.5%[5]	11.66kV	10.93kV (10.50kV)[1]	11.66kV	10.34kV (9.90kV)[1]
+5%	11.59kV	10.68kV (10.25kV)[1]		
+2.5%	11.31kV	10.42kV (10.01kV)[1]		
0	11.04kV	10.17kV (9.77kV)[1]		
-2.5%	10.76kV	9.92kV (9.52kV)[1]		
-5%	10.49kV	9.66kV (9.28kV)[1]		

Note:

[1] The minimum values in brackets only apply under abnormal feeding arrangements. Further guidance on the application of these values is given in 3.1.4.

[2] The maximum voltage values apply under both normal and abnormal feeding arrangements.

[3] Under no circumstances shall the RMS voltage on the 11kV network exceed 12kV.

[4] The transformer tap numbers apply to transformers with 5 tap positions. Some small transformers only have 3 tap positions (+5%, 0 and -5%).

[5] At the time of issue of this document distribution transformers are specified with a tap range of +5% to -5%. This tap range is expected to change to +7.5% to -2.5% in the future.

Table 2 Voltage Limits on the 6.6kV 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%[5]	7.00kV	6.61kV (6.35kV)[1]		
+5%[5]	6.95kV	6.41kV (6.15kV)[1]		
+4.2%[5]	6.90kV	6.36kV (6.10kV)[1]		
+2.5%[5]	6.79kV	6.25kV (6.01kV)[1]		
0	6.62kV	6.10kV (5.86kV)[1]	7.00kV	6.20kV (5.94kV)[1]
-2.5%[5]	6.46kV	5.95kV (5.71kV)[1]		
-4.2%[5]	6.35kV	5.85kV (5.62kV)[1]		
-5%[5]	6.29kV	5.80kV (5.57kV)[1]		
-8.4%[5]	6.07kV	5.59kV (5.37kV)[1]		

Note:

[1] The minimum values in brackets only apply under abnormal feeding arrangements. Further guidance on the application of these values is given in 3.1.4.

[2] The maximum voltage values apply under both normal and abnormal feeding arrangements.

[3] Under no circumstances shall the RMS voltage on the 6.6kV network exceed 7.2kV.

[4] The transformer tap numbers apply to transformers with 5 tap positions. Some small transformers only have 3 tap positions (e.g. +5%, 0 and -5%).

[5] 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 3: 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
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%

[1] *Where power flow is in the conventional direction, i.e. from the HV side to the LV side of the transformer, positive figures indicate voltage drop values and negative figures (i.e. the shaded areas) indicate voltage rise values. This convention is reversed where power flow is in the opposite direction (e.g. due to generation).*

[2] *A demand customer with a leading power factor imports real power and exports reactive power. A generator operating with a leading power factor exports real power (kW) and imports reactive power (kVAR)*

Table 3 (continued): Voltage Drop 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%

[1] *Where power flow is in the conventional direction, i.e. from the HV side to the LV side of the transformer, positive figures indicate voltage drop values and negative figures (i.e. the shaded areas) indicate voltage rise values. This convention is reversed where power flow is in the opposite direction (e.g. due to generation).*

[2] *A demand customer with a leading power factor imports real power and exports reactive power. A generator operating with a leading power factor exports real power (kW) and imports reactive power (kVAR)*

APPENDIX A

SUPERSEDED DOCUMENTATION

This document supersedes POL:SD4/7 dated September 2017 which has now be withdrawn.

APPENDIX B

ANCILLARY DOCUMENTATION

ENA EREC P2, Security of Supply

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

ENA EREC P28, Planning limits for voltage fluctuations caused by Industrial, Commercial and Domestic equipment in the United Kingdom

ENA EREC G5, Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission systems and distribution networks in the United Kingdom.

ENA EREC G59, Recommendations for the connection of generating plant to the electricity systems of Licensed Distribution Network Operators.

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

ENA EREC G74, Procedure to meet the requirements of IEC 909 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

ST:AM5C, Technical Appraisal Approval and Post Investment Appraisal for Network Related Capital Projects

POL:FI 06/04/01, Capital expenditure and project management - Investment appraisal, financial recommendation, and approval of capital sanctions

APPENDIX C

KEY WORDS

HV, system, design, security, imbalance, fluctuation, harmonics, utilisation, regulation.