Electricity Distribution

nationalgrid

Company Directive

STANDARD TECHNIQUE: SD1H/2

The Treatment of Losses in an Inclusive Network Design Process

Summary

This document sets out the considerations that are to be applied regarding losses when undertaking network design studies.

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Implementation Date: June 2019

Approved by

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Date: 3 June 2019

All references to Western Power Distribution or WPD must be read as National Grid Electricity Distribution or NGED

IMPLEMENTATION PLAN

Introduction

This Standard Technique details the high level approach for considering losses as part of network design and operations.

Main Changes

Additional losses tables have been added to Appendix B.

Impact of Changes

None.

Implementation Actions

Team Managers responsible for PSD planners shall make them aware of the new tables.

Implementation Timetable

This document can be implemented with immediate effect.

REVISION HISTORY

Document Revision & Review Table		
Date	**Comments**	**Author**
June 2019	• Addition of 33kV STOR profile to EHV generation losses tables in Appendix B • Update of 33kV Other profile to EHV generation losses tables in Appendix B • Addition of conductor materials to demand and generation EHV losses tables in Appendix B	Joshua Edmonds
April 2017	• Addition of West Midlands 66kV demand and generation EHV losses tables in Appendix B	Seth Treasure/Sam Donnelly

1.0 INTRODUCTION

1.1 WPD 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 can be reasonably expected to ensure losses are as low as reasonably practicable.

1.2 The Losses Strategy includes details of actions and interventions that we are planning to deliver during ED1 plus a table of expected outputs.

2.0 LOSSES STRATEGY

2.1 The Losses Strategy is developed by the Policy Manager, and is subject to annual review and update.

2.2 The Losses Strategy details actions and interventions which have provided a positive CBA and can be applied in all cases. They include:

- A minimum low voltage and high voltage cable CSA of 185mm^2 when used as a mains cable.
- A minimum service cable CSA of 25mm^2 Cu or 35mm^2 Al.
- A minimum ground mounted distribution transformer size of 500 kVA
- A minimum pole mounted distribution transformer size of 25kVA (single phase) and 50kVA (three phase).
- The proactive replacement of all ground mounted transformers manufactured before 1958.

3.0 APPLICATION OF INTERVENTIONS DETAILED IN THE LOSSES STRATEGY

3.1 Where a Losses Strategy intervention requires a change to company policy or procedure it will be communicated through a new or revised Standard Technique or Specification document. Where the change affects new connection design standards or materials it will also be communicated through a revision to the G81 suite of documents.

4.0 DESIGN CONSIDERATIONS ON THE LOW VOLTAGE AND HIGH VOLTAGE NETWORK

4.1 Planners who design alterations and extensions to the low voltage and 11kV networks follow the suite of guidance contained within the SD suite of documents. By applying these documents and using the minimum equipment sizes detailed in the relevant EE specifications planners will have achieved a loss inclusive design solution.

5.0 DESIGN CONSIDERATIONS ON THE 33,000 VOLT NETWORK AND ABOVE FOR NEW CONNECTIONS

5.1 For the design of new connections to the network, planners are to use the tables provided in Appendix B to assess the electrical losses and select the appropriate cable based on the capacity of the connection. The tables in Appendix B are based on a single circuit to the new connection.

5.2 A cost benefit analysis (CBA) has been completed using the cable loss estimating tool. The tool compares the additional cost of using the next cable size up against the potential loss savings of using the larger cable. The CBA is based on the expected life of the asset i.e. 40 years for cables, the Ofgem societal cost of losses figure of £48.42/MWh and an NPV discount rate of 3.5%.

5.3 In the case where the increase in the size of cable provides a positive payback period i.e. less than 40 years for cables, this becomes the most cost effective solution for the life of the asset and will become the WPD minimum scheme. This applies to all designs on the WPD network, regardless of whether the work is being undertaken by an ICP or WPD. This ST works in conjunction with POL:SP3.

5.4 Examples of new connections are shown in Appendix A. The new connection assets are highlighted in red. The cable sections of the new assets shall be designed with consideration of the table contents in Appendix B.

5.5 For the design of new connections to the network where a firm connection has been requested i.e. two circuits, shown by Figure 4 in Appendix A. It shall be assumed that the most frequent running arrangement, and that to be used in the consideration of losses, is to have all circuits of the new connection assets in service. For example where two circuits are offered, it shall be assumed that each circuit carries half of the requested capacity.

6.0 DESIGN CONSIDERATIONS ON THE 33,000 VOLT NETWORK AND ABOVE FOR NETWORK REINFORCEMENT AND ASSET REPLACEMENT

6.1 Any cable overlay for reinforcement schemes triggered by a new connection shall give consideration to uprating any necessary assets utilising the same process as the new connection sole use assets above.

6.2 Where the planner is considering the design of network reinforcement or asset replacement, the cable sections need to account for losses, however the impact on power flows due to upsizing of assets must be evaluated. For example, Figure 5 in Appendix A shows a ring network with a new loop in generator connection. The upsizing of a cable section shall not be designed to the detriment of other cable sections. For instance, if it is proved beneficial to upsize cable section B for losses purposes, but has an adverse effect on cable sections C, D and E, then the cable should only be upsized if the calculated benefits of upsizing cable section B outweigh the disadvantages it may cause to the existing network.

7.0 LOSSES CALCULATION PROCESS

7.1 The I^2R losses figure for each scheme has been calculated using a representative demand or generation profile for each DNO license area. The I^2R losses for cables are calculated based on the following parameters:

- AC Resistance
  - The AC resistance value of each cable has been adjusted to approximately 45°C.
  - The skin and proximity effect values have been applied to each cable AC resistance value.

- Current
  - The AC current values used in the calculations are derived from profiles based on the type of connection and the area in which they are connecting.

7.2 As mentioned above there are generation and demand profiles bespoke to each DNO license area. There are eight types of demand for the planners to base their assessment on when considering the 33kV and 66kV networks. These are:

- Commercial - City/Town centre consisting of shops, accommodation and offices
- Domestic Rural - Rural area consisting of mainly accommodation
- Domestic Urban - Urban area consisting of mainly accommodation
- Industrial - Industrial area consisting of factories etc.
- Mixed - Combination of commercial, domestic and industrial
- 50% - Constant 50% loading on the circuit
- 75% - Constant 75% loading on the circuit
- 100% - Constant 100% loading on the circuit

Due to the unique nature of each GSP/BSP, the 132kV demand types have been split into nine percentage based profiles, these are:

- 50%, 60%, 70%, 75%, 80%, 85%, 90%, 95%, 100% - Constant relevant percentage loading on the circuit

There are four types of generation for the planners to base their assessments on for all voltage levels. These are:

- Other – Generation including Biomass, STOR and battery, where the generator is assumed to have a constant 100% output
- STOR – STOR generation operating with an approximately 50% average output profile. An example is provided in Appendix D

- PV – Photovoltaic generation
- Wind – Wind Power generation

7.3 Where a new connection is required the I^2R losses have been calculated for the sole use cable sections based on a generation output or demand profile for the associated DNO license area i.e. wind generation or commercial load in Wales. The I^2R losses for each cable type at the required voltage level have then be calculated and compared against the cost of 'upsizing' the associated cable section and its payback period. The results of these calculations have been summarised into tables in Appendix B.

7.4 A net present value (NPV) calculation has been completed using the cable loss estimating tool. These calculations provide a payback period for upsizing the cable against the lower size cable. The NPV discount rate has been set to 3.5% and the life expectancy of the asset to 40 years. The formula for the NPV calculation can be found in Appendix C.

7.5 The rows highlighted in grey in the tables in Appendix B indicate that a study has been performed, however it would be highly improbable to provide this capacity of demand/generation at the given voltage level. A bespoke study shall be completed for capacities in this range.

NETWORK EXAMPLES

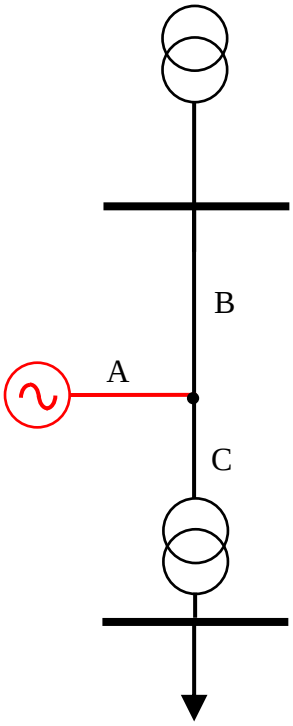

Figure 1, tee in connection

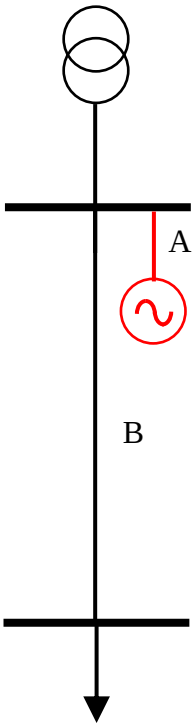

Figure 2, direct circuit connection

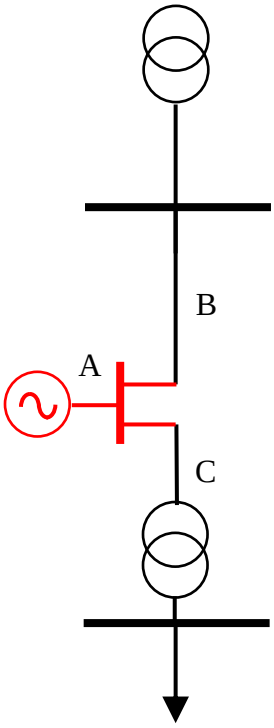

Figure 3, loop in connection

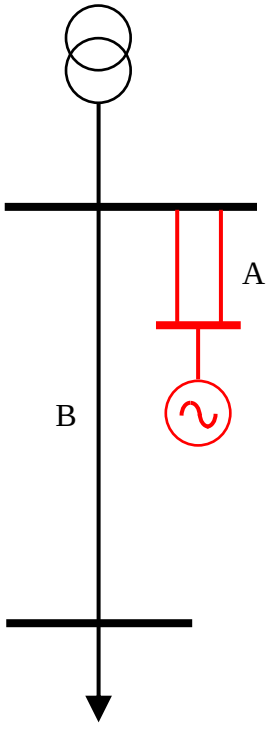

Figure 4, direct circuit firm connection

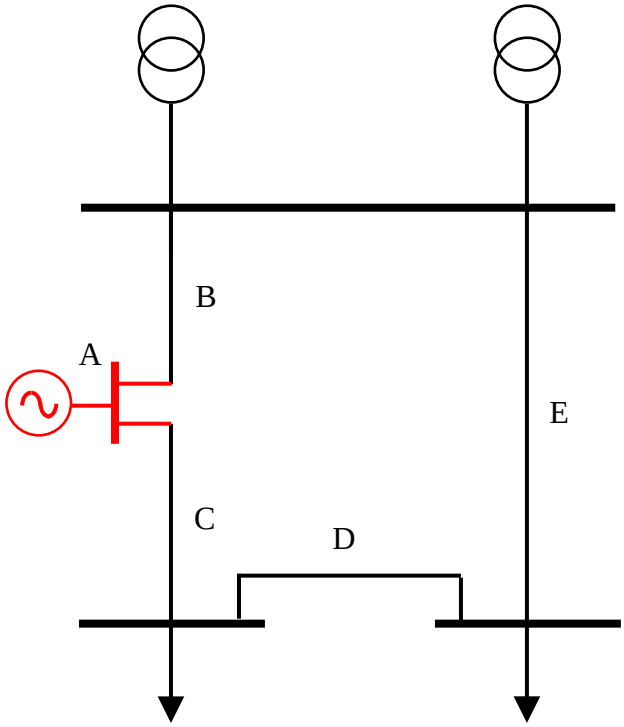

Figure 5, loop in connection on a ring network

APPENDIX B

EHV LOSSES TABLES

East EHV Midlands Losses Tables

Table 1, East Midlands 33kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Commercial	0.00	10.70	185
	10.70	17.70	300
	17.70	25.30	400
	25.30	54.25	630
	54.25	54.25+	800
Domestic Rural	0.00	14.00	185
	14.00	23.00	300
	23.00	32.90	400
	32.90	70.55	630
	70.55	70.55+	800
Domestic Urban	0.00	12.95	185
	12.95	21.25	300
	21.25	30.40	400
	30.40	65.15	630
	65.15	65.15+	800
Industrial	0.00	13.00	185
	13.00	21.30	300
	21.30	30.50	400
	30.50	65.35	630
	65.35	65.35+	800
Mixed	0.00	11.65	185
	11.65	19.10	300
	19.10	27.35	400
	27.35	58.60	630
	58.60	58.60+	800
50%	0.00	12.90	185
	12.90	21.15	300
	21.15	30.25	400
	30.25	64.90	630
	64.90	64.90+	800
75%	0.00	8.60	185
	8.60	14.10	300
	14.10	20.20	400
	20.20	43.30	630
	43.30	43.30+	800
100%	0.00	6.45	185
	6.45	10.60	300
	10.60	15.15	400
	15.15	32.45	630
	32.45	32.45+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, $35mm^2$ Copper Wire Screened

Table 2, East Midlands 132kV Demand Losses Table

Demand Type	Capacity		Selected Cable (mm^2)*
	From	Up To	
50%	0.00	115.80	300
	115.80	222.20	630
	222.20	465.00	1000
	465.00	559.00	1600
	559.00	559.00+	2000
60%	0.00	96.50	300
	96.50	185.17	630
	185.17	387.50	1000
	387.50	465.83	1600
	465.85	465.85+	2000
70%	0.00	82.70	300
	82.70	158.70	630
	158.70	332.15	1000
	332.15	399.30	1600
	399.30	399.30+	2000
75%	0.00	77.20	300
	77.20	148.15	630
	148.15	310.00	1000
	310.00	372.70	1600
	372.70	372.65+	2000
80%	0.00	72.40	300
	72.40	138.90	630
	138.90	290.65	1000
	290.65	349.40	1600
	349.40	349.40+	2000
85%	0.00	68.10	300
	68.10	130.70	630
	130.70	273.55	1000
	273.55	328.80	1600
	328.80	328.80+	2000
90%	0.00	64.35	300
	64.35	123.45	630
	123.45	258.35	1000
	258.35	310.55	1600
	310.55	310.55+	2000
95%	0.00	60.95	300
	60.95	116.95	630
	116.95	244.75	1000
	244.75	294.20	1600
	294.20	294.20+	2000
100%	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

Table 3, East Midlands 33kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	8.05	185
	8.05	11.30	300
	11.30	17.55	400
	17.55	26.45	630
	26.45	26.45+	800
STOR (~50% Output)	0.00	11.40	185
	11.40	16.05	300
	16.05	25.40	400
	25.40	38.25	630
	38.25	38.25+	800
PV	0.00	23.60	185
	23.60	38.75	300
	38.75	55.45	400
	55.45	118.90	630
	118.90	118.90+	800
Wind	0.00	15.90	185
	15.90	26.10	300
	26.10	37.25	400
	37.25	80.10	630
	80.10	80.10+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, 35mm^2 Copper Wire Screened

Table 4, East Midlands 132kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000
PV	0.00	212.15	300
	212.15	406.90	630
	406.90	850.90	1000
	850.90	1024.05	1600
	1024.05	1024.05+	2000
Wind	0.00	142.80	300
	142.80	273.90	630
	273.90	572.75	1000
	572.75	689.30	1600
	689.30	689.30+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

South West EHV Losses Tables

Table 5, South West 33kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Commercial	0.00	12.20	185
	12.20	20.05	300
	20.05	28.70	400
	28.70	61.50	630
	61.50	61.50+	800
Domestic Rural	0.00	14.30	185
	14.30	23.45	300
	23.45	33.55	400
	33.55	71.95	630
	71.95	71.95+	800
Domestic Urban	0.00	13.50	185
	13.50	22.15	300
	22.15	31.70	400
	31.70	68.00	630
	68.00	68.00+	800
Industrial	0.00	12.10	185
	12.10	19.80	300
	19.80	28.35	400
	28.35	60.80	630
	60.80	60.80+	800
Mixed	0.00	10.30	185
	10.30	16.90	300
	16.90	24.20	400
	24.20	51.85	630
	51.85	51.85+	800
50%	0.00	12.90	185
	12.90	21.15	300
	21.15	30.25	400
	30.25	64.90	630
	64.90	64.90+	800
75%	0.00	8.60	185
	8.60	14.10	300
	14.10	20.20	400
	20.20	43.30	630
	43.30	43.30+	800
100%	0.00	6.45	185
	6.45	10.60	300
	10.60	15.15	400
	15.15	32.45	630
	32.45	32.45+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, 35mm^2 Copper Wire Screened

Table 6, South West 132kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
50%	0.00	115.80	300
	115.80	222.20	630
	222.20	465.00	1000
	465.00	559.00	1600
	559.00	559.00+	2000
60%	0.00	96.50	300
	96.50	185.20	630
	185.20	387.50	1000
	387.50	465.85	1600
	465.85	465.85+	2000
70%	0.00	82.70	300
	82.70	158.70	630
	158.70	332.15	1000
	332.15	399.30	1600
	399.30	399.30+	2000
75%	0.00	77.20	300
	77.20	148.15	630
	148.15	310.00	1000
	310.00	372.65	1600
	372.65	372.65+	2000
80%	0.00	72.40	300
	72.40	138.90	630
	138.90	290.65	1000
	290.65	349.40	1600
	349.40	349.40+	2000
85%	0.00	68.10	300
	68.10	130.70	630
	130.70	273.55	1000
	273.55	328.80	1600
	328.80	328.80+	2000
90%	0.00	64.35	300
	64.35	123.45	630
	123.45	258.35	1000
	258.35	310.55	1600
	310.55	310.55+	2000
95%	0.00	60.95	300
	60.95	116.95	630
	116.95	244.75	1000
	244.75	294.20	1600
	294.20	294.20+	2000
100%	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

Table 7, South West 33kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	8.05	185
	8.05	11.30	300
	11.30	17.55	400
	17.55	26.45	630
	26.45	26.45+	800
STOR (~50% Output)	0.00	11.40	185
	11.40	16.05	300
	16.05	25.40	400
	25.40	38.25	630
	38.25	38.25+	800
PV	0.00	19.75	185
	19.75	32.45	300
	32.45	46.40	400
	46.40	99.50	630
	99.50	99.50+	800
Wind	0.00	16.90	185
	16.90	27.75	300
	27.75	39.65	400
	39.65	85.10	630
	85.10	85.10+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, 35mm^2 Copper Wire Screened

Table 8, South West 132kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000
PV	0.00	177.55	300
	177.55	340.55	630
	340.55	712.10	1000
	712.10	857.00	1600
	857.00	857.00+	2000
Wind	0.00	151.75	300
	151.75	291.05	630
	291.05	608.60	1000
	608.60	732.45	1600
	732.45	732.45+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

Wales EHV Losses Tables

Table 9, Wales 33kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Commercial	0.00	11.10	185
	11.10	18.25	300
	18.25	26.10	400
	26.10	55.95	630
	55.95	55.95+	800
Domestic Rural	0.00	12.50	185
	12.50	20.55	300
	20.55	29.40	400
	29.40	63.00	630
	63.00	63.00+	800
Domestic Urban	0.00	10.80	185
	10.80	17.70	300
	17.70	25.35	400
	25.35	54.35	630
	54.35	54.35+	800
Industrial	0.00	10.20	185
	10.20	16.70	300
	16.70	23.90	400
	23.90	51.20	630
	51.20	51.20+	800
Mixed	0.00	10.85	185
	10.85	17.75	300
	17.75	25.40	400
	25.40	54.50	630
	54.50	54.50+	800
50%	0.00	12.90	185
	12.90	21.15	300
	21.15	30.25	400
	30.25	64.90	630
	64.90	64.90+	800
75%	0.00	8.60	185
	8.60	14.10	300
	14.10	20.20	400
	20.20	43.30	630
	43.30	43.30+	800
100%	0.00	6.45	185
	6.45	10.60	300
	10.60	15.15	400
	15.15	32.45	630
	32.45	32.45+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, $35mm^2$ Copper Wire Screened

Table 10, Wales 66kV Demand Losses Table

Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Commercial	0.00	27.55	185
	N/A†	N/A†	300†
	27.55	54.25	400
	54.25	86.90	630
	86.90	86.90+	1000
Domestic Rural	0.00	31.05	185
	N/A†	N/A†	300†
	31.05	61.10	400
	61.10	97.90	630
	97.90	97.90+	1000
Domestic Urban	0.00	26.75	185
	N/A†	N/A†	300†
	26.75	52.70	400
	52.70	84.40	630
	84.40	84.40+	1000
Industrial	0.00	25.25	185
	N/A†	N/A†	300†
	25.25	49.70	400
	49.70	79.60	630
	79.60	79.60+	1000
Mixed	0.00	26.85	185
	N/A†	N/A†	300†
	26.85	52.85	400
	52.85	84.65	630
	84.65	84.65+	1000
50%	0.00	32.00	185
	N/A†	N/A†	300†
	32.00	63.00	400
	63.00	100.90	630
	100.90	100.90+	1000
75%	0.00	21.35	185
	N/A†	N/A†	300†
	21.35	42.00	400
	42.00	67.20	630
	67.20	67.20+	1000
100%	0.00	16.00	185
	N/A†	N/A†	300†
	16.00	31.50	400
	31.50	50.45	630
	50.45	50.45+	1000

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, Copper Wire Screened

†$300mm^2$ becomes obsolete due to standard price of $400mm^2$

Table 11, Wales 132kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
50%	0.00	115.80	300
	115.80	222.20	630
	222.20	465.00	1000
	465.00	559.00	1600
	559.00	559.00+	2000
60%	0.00	96.50	300
	96.50	185.20	630
	185.20	387.50	1000
	387.50	465.85	1600
	465.85	465.85+	2000
70%	0.00	82.70	300
	82.70	158.70	630
	158.70	332.15	1000
	332.15	399.30	1600
	399.30	399.30+	2000
75%	0.00	77.20	300
	77.20	148.15	630
	148.15	310.00	1000
	310.00	372.65	1600
	372.65	372.65+	2000
80%	0.00	72.40	300
	72.40	138.90	630
	138.90	290.65	1000
	290.65	349.40	1600
	349.40	349.40+	2000
85%	0.00	68.10	300
	68.10	130.70	630
	130.70	273.55	1000
	273.55	328.80	1600
	328.80	328.80+	2000
90%	0.00	64.35	300
	64.35	123.45	630
	123.44	258.33	1000
	258.35	310.55	1600
	310.55	310.55+	2000
95%	0.00	60.95	300
	60.95	116.95	630
	116.95	244.75	1000
	244.75	294.20	1600
	294.20	294.20+	2000
100%	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

Table 12, Wales 33kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	8.05	185
	8.05	11.30	300
	11.30	17.55	400
	17.55	26.45	630
	26.45	26.45+	800
STOR (~50% Output)	0.00	11.40	185
	11.40	16.05	300
	16.05	25.40	400
	25.40	38.25	630
	38.25	38.25+	800
PV	0.00	23.85	185
	23.85	39.15	300
	39.15	56.00	400
	56.00	120.10	630
	120.10	120.10+	800
Wind	0.00	14.20	185
	14.20	23.30	300
	23.30	33.30	400
	33.30	71.50	630
	71.50	71.50+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, $35mm^2$ Copper Wire Screened

Table 13, Wales 66kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	16.00	185
	N/A†	N/A†	300†
	16.00	31.50	400
	31.50	50.45	630
	50.45	50.45+	1000
PV	0.00	59.15	185
	N/A†	N/A†	300†
	59.15	116.45	400
	116.45	186.60	630
	186.60	186.60+	1000
Wind	0.00	35.25	185
	N/A†	N/A†	300†
	32.25	69.35	400
	69.35	111.10	630
	111.10	111.10+	1000

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, Copper Wire Screened

†$300mm^2$ becomes obsolete due to standard price of $400mm^2$

Table 14, Wales 132kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Other	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000
PV	0.00	214.30	300
	214.30	411.05	630
	411.05	859.45	1000
	859.45	1034.35	1600
	1034.35	1034.35+	2000
Wind	0.00	127.60	300
	127.60	244.80	630
	244.80	511.80	1000
	511.80	616.00	1600
	616.00	616.00+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

West Midlands EHV Losses Tables

Table 15, West Midlands 33kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Commercial	0.00	11.40	185
	11.40	18.70	300
	18.70	26.70	400
	26.70	57.30	630
	57.30	57.30+	800
Domestic Rural	0.00	14.45	185
	14.45	23.75	300
	23.75	33.95	400
	33.95	72.80	630
	72.80	72.80+	800
Domestic Urban	0.00	11.20	185
	11.20	18.40	300
	18.40	26.30	400
	26.30	56.40	630
	56.40	56.40+	800
Industrial	0.00	10.55	185
	10.55	17.30	300
	17.30	24.75	400
	24.75	53.10	630
	53.10	53.10+	800
Mixed	0.00	10.50	185
	10.50	17.25	300
	17.25	24.65	400
	24.65	52.85	630
	52.85	52.85+	800
50%	0.00	12.90	185
	12.90	21.15	300
	21.15	30.25	400
	30.25	64.90	630
	64.90	64.90+	800
75%	0.00	8.60	185
	8.60	14.10	300
	14.10	20.20	400
	20.20	43.30	630
	43.30	43.30+	800
100%	0.00	6.45	185
	6.45	10.60	300
	10.60	15.15	400
	15.15	32.45	630
	32.45	32.45+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, $35mm^2$ Copper Wire Screened

Table 16, West Midlands 66kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)*
	From	Up To	
Commercial	0.00	28.20	185
	N/A†	N/A†	300†
	28.20	55.55	400
	55.55	89.00	630
	89.00	89.00+	1000
Domestic Rural	0.00	35.85	185
	N/A†	N/A†	300†
	35.85	70.60	400
	70.60	113.10	630
	113.10	113.10+	1000
Domestic Urban	0.00	27.80	185
	N/A†	N/A†	300†
	27.80	54.70	400
	54.70	87.60	630
	87.60	87.60+	1000
Industrial	0.00	26.15	185
	N/A†	N/A†	300†
	26.15	51.50	400
	51.50	82.50	630
	82.50	82.50+	1000
Mixed	0.00	31.92	185
	N/A†	N/A†	300†
	31.92	62.94	400
	62.94	100.80	630
	100.80	25.25+	1000
50%	0.00	32.00	185
	N/A†	N/A†	300†
	32.00	62.95	400
	62.95	100.85	630
	100.85	100.85+	1000
75%	0.00	21.35	185
	N/A†	N/A†	300†
	21.35	42.00	400
	42.00	67.25	630
	67.25	67.25+	1000
100%	0.00	16.00	185
	N/A†	N/A†	300†
	16.00	31.50	400
	31.50	50.45	630
	50.45	50.45+	1000

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, Copper Wire Screened

†300mm^2 becomes obsolete due to standard price of 400mm^2

Table 17, West Midlands 132kV Demand Losses Table

Demand Type	Capacity (MW)		Selected Cable (mm^2)
	From	Up To	
50%	0.00	115.80	300
	115.80	222.20	630
	222.20	465.00	1000
	465.00	559.00	1600
	559.00	559.00+	2000
60%	0.00	96.50	300
	96.50	185.20	630
	185.20	387.50	1000
	387.50	465.85	1600
	465.85	465.85+	2000
70%	0.00	82.70	300
	82.70	158.70	630
	158.70	332.15	1000
	332.15	399.30	1600
	399.30	399.30+	2000
75%	0.00	77.20	300
	77.20	148.15	630
	148.15	310.00	1000
	310.00	372.65	1600
	372.65	372.65+	2000
80%	0.00	72.40	300
	72.40	138.90	630
	138.90	290.65	1000
	290.65	349.40	1600
	349.40	349.40+	2000
85%	0.00	68.10	300
	68.10	130.70	630
	130.70	273.55	1000
	273.55	328.80	1600
	328.80	328.80+	2000
90%	0.00	64.35	300
	64.35	123.45	630
	123.45	258.35	1000
	258.35	310.55	1600
	310.55	310.55+	2000
95%	0.00	60.95	300
	60.95	116.95	630
	116.95	244.75	1000
	244.75	294.20	1600
	294.20	294.20+	2000
100%	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

Table 18, West Midlands 33kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)
	From	Up To	
Other	0.00	8.05	185
	8.05	11.30	300
	11.30	17.55	400
	17.55	26.45	630
	26.45	26.45+	800
STOR (~50% Output)	0.00	11.40	185
	11.40	16.05	300
	16.05	25.40	400
	25.40	38.25	630
	38.25	38.25+	800
PV	0.00	24.90	185
	24.90	40.90	300
	40.90	58.50	400
	58.50	125.50	630
	125.50	125.50+	800

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, $35mm^2$ Copper Wire Screened

Table 19, West Midlands 66kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)
	From	Up To	
Other	0.00	16.00	185
	N/A†	N/A†	300†
	16.00	31.50	400
	31.50	50.45	630
	50.45	50.45+	1000
PV	0.00	61.80	185
	N/A†	N/A†	300†
	61.80	121.70	400
	121.70	195.00	630
	195.00	195.00+	1000

*Ethylene Propylene Rubber Insulated, Stranded Copper Conductor, Copper Wire Screened

†$300mm^2$ becomes obsolete due to standard price of $400mm^2$

Table 20, West Midlands 132kV Generation Losses Table

Generation Type	Capacity (MW)		Selected Cable (mm^2)
	From	Up To	
Other	0.00	57.90	300
	57.90	111.10	630
	111.10	232.50	1000
	232.50	279.50	1600
	279.50	279.50+	2000
PV	0.00	223.95	300
	223.95	429.55	630
	429.55	898.20	1000
	898.20	1081.00	1600
	1081.00	1081.00+	2000

*XLPE insulation, Stranded Copper Conductor, Lead Sheath

APPENDIX C

CABLE LOSS CALCULATION PROCEDURE

1. Obtain a power output/demand profile for the connection type and area e.g. South Wales Wind or South Wales Commercial

2. Calculate the equivalent yearly MW output/demand profile based on the connecting generator/load capacity e.g. 10 MW Wind Farm

$$\text{MW Output} = \text{Output \%} \times \text{Generator Capacity (MW)}$$

3. Calculate the current output/demand using the yearly MW profile and connecting voltage e.g. 33 kV

$$Current\ Output = \frac{MW\ Output}{\sqrt{3} \times Voltage}(A)$$

4. Calculate the hours per year for each MW output/demand

$$Hours\ per\ year = Annual\ \% * 8766\ (Hours)$$

5. Calculate total resistance of circuit

$$Total\ Resistance = Cable\ Resistance\ at\ 45°C \times Distance\ (\Omega)$$

6. Calculate loss per core for each power output/demand

$$kWh = (Current\ Output)^2 \times Total\ Resistance \times Hours\ per\ year$$

7. Repeat steps 2-6 for each power output/demand, then sum up to get a total kWh loss per core

8. Multiply by 3 to get total three phase system losses i.e. Total kWh Losses

9. Calculate the Annual Loss Cost for the chosen cable

$$Annual\ Loss = Total\ kWh\ losses \times £0.04842$$

10. By repeating steps 5 to 9 above for another cable with a different CSA, the loss saving can be calculated

$$Loss\ Saving = Annual\ Loss\ Cable\ A - Annual\ Loss\ Cable\ B$$

11. Calculate the cost of upsizing the cable section

$$Upsizing\ Cost = Install\ Cost\ Cable\ B - Install\ Cost\ Cable\ A$$

12. Calculate the payback period for upsizing the cable

$$Payback\ period = \frac{Upsizing\ Cost}{NPV\ of\ Loss\ Saving\ at\ 3.5\%}$$

<u>Cable Resistance Calculations</u>

1. The AC resistance at θ°C, taking into account both the skin and proximity effect is calculated using:

$$R = R'(1 + y_s + y_p)$$

2. The DC resistance needs to be calculated first using the DC resistance at 20°C of the cable provided in the manufacturers datasheet

$$R' = R_{20}[1 + \alpha_{20}(\theta - 20)]$$

3. The skin effect is calculated using the following equation:

$$y_s = \frac{{x_s}^4}{192 + 0.8{x_s}^4}$$

Where,

$${x_s}^2 = \frac{8\pi f}{R'}.10^{-7}.k_s$$

4. The proximity effect is calculated using the following equation:

$$y_p = \frac{{x_p}^4}{192 + 0.8{x_p}^4}\left(\frac{d_c}{s}\right)^2\left[0.312(\frac{d_c}{s})^2 + \frac{1.18}{\frac{{x_p}^4}{192 + 0.8{x_p}^4} + 0.27}\right]$$

Where,

$${x_p}^2 = \frac{8\pi f}{R'}.10^{-7}.k_p$$

Table 21, Cable Resistance Calculation Parameters

R		Rac at θ°C
R'		Rdc at θ°C
ys		skin effect factor
yp		proximity effect factor
R20		DC Resistance of conductor at 20°C
θ°C		Maximum Operating Temperature in °C
α20Cu	0.00393	Constant Mass Temperature coefficients Cu
α20Al	0.00403	Constant Mass Temperature coefficients Al
f	50	supply frequency in Hz
ks	1	Skin effect coefficient
kp	1	Proximity effect coefficient
dc		diameter of conductor (mm)
s		distance between conductor axes (mm)
π	3.14159	

NPV Calculations

1. The payback period for upsizing the cable is calculated by applying an NPV discount rate to the annual loss saving of each option. The values for the parameters in the equation below are shown in Table 22.

$$\sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_O$$

Table 22, NPV Parameters

t	1-40	Time period of the cash flow (Years)
T	40	Total number of time periods the NPV is being calculated (Years)
r	3.5%	Discount rate (%)
Ct	Loss Saving	Net cash flow at time period t (£)
Co	Upsize Cost	Initial investment at the time period 0

APPENDIX D

EXAMPLE STOR GENERATOR EXPORT PROFILE

Example of the maximum export profile of a 20kW STOR generator connected at 33kV which represents an average output of approximately 50%. The STOR category in the EHV Losses Tables in Appendix B was calculated using this profile and thus should only be applied to STOR generators with reasonably similar profiles.

UK Clock Time	Maximum Export (kVA)			
	Winter		Summer	
	Working Day	Non-Working Day	Working Day	Non-Working Day
0000-0530				
0530-0600	10000		10000	
0600-0630	20000		20000	
0630-0700	20000		20000	
0700-0730	20000		20000	
0730-0800	20000		20000	
0800-0830	20000		20000	
0830-0900	20000		20000	
0900-0930	20000		20000	
0930-1000	20000		20000	10000
1000-1030	20000	10000	20000	20000
1030-1100	20000	20000	20000	20000
1100-1030	20000	20000	20000	20000
1130-1200	20000	20000	20000	20000
1200-1230	20000	20000	20000	20000
1230-1300	20000	20000	20000	20000
1300-1330	10000	20000	20000	20000
1330-1400	-	10000	20000	20000
1400-1430	-		10000	10000
1430-1500	-		-	-
1500-1530	-	-	-	-
1530-1600	10000	10000	10000	-
1600-1630	20000	20000	20000	10000
1630-1700	20000	20000	20000	20000
1700-1730	20000	20000	20000	20000
1730-1800	20000	20000	20000	20000
1800-1830	20000	20000	20000	20000
1830-1900	20000	20000	20000	20000
1900-1930	20000	20000	20000	20000
1930-2000	20000	20000	20000	20000
2000-2030	20000	10000	20000	20000
2030-2100	10000	-	20000	20000
2100-2130	-	-	20000	20000
2130-2200	-	-	20000	20000
2200-2230	-	-	10000	10000
2230-2400	-	-	-	-

Winter – The months of October, November, December, January, February and March
Summer – Any month that is not Winter
Working Day – Any day other than a Saturday, a Sunday, Christmas Day, Good Friday or a day which is considered a bank holiday within the Banking and Financial Dealings Act 1971
Non-Working Day – Any day that is not a Working Day

APPENDIX E

SUPERSEDED DOCUMENTATION

This document supersedes ST:SD1H/1 dated April 2017 which has now been withdrawn.

APPENDIX F

ASSOCIATED DOCUMENTATION

POL:CA1, POL:CA2, POL:CA3, POL:SD4, POL:SD5 and associated STs
WPD G81 Part 1 Design Framework Appendix

APPENDIX G

KEY WORDS

Losses, Design, Ofgem, CBA, NPV