

Company Directive

STANDARD TECHNIQUE: SD1H/1

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: April 2017

Approved by



Policy Manager

Date:

5 April 2017

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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.

| Document Revision & Review Table | | |
|---|--|----------------------------|
| Date | Comments | Author |
| April 2017 | <ul style="list-style-type: none"> • 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 185mm² when used as a mains cable.
 - A minimum service cable CSA of 25mm² Cu or 35mm² 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 upgrading 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 three 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.
- 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

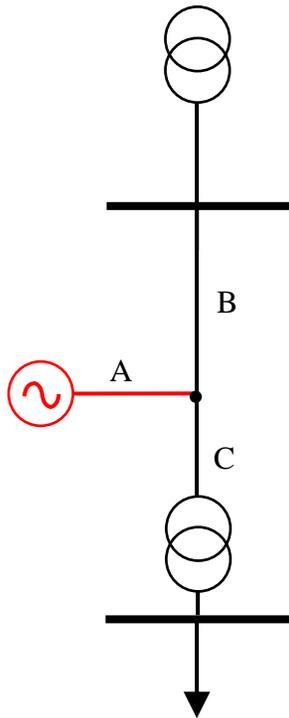


Figure 1. tee in connection

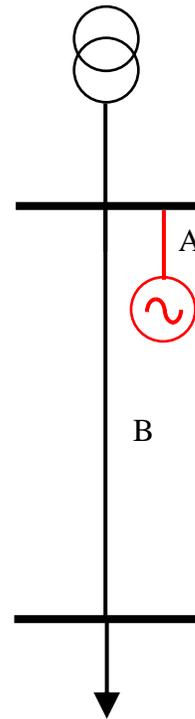


Figure 2. direct circuit connection

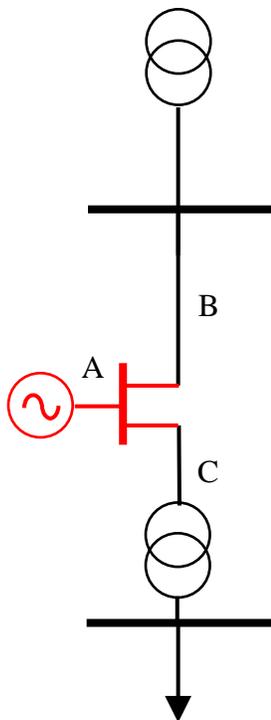


Figure 3. loop in connection

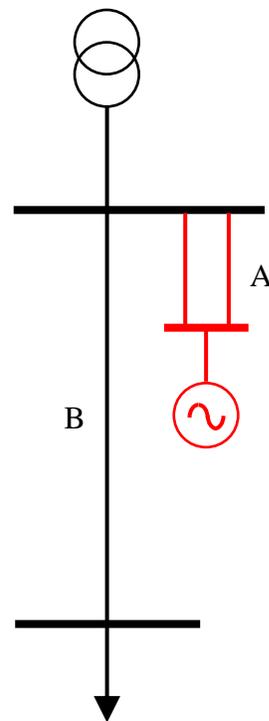


Figure 1. direct circuit firm connection

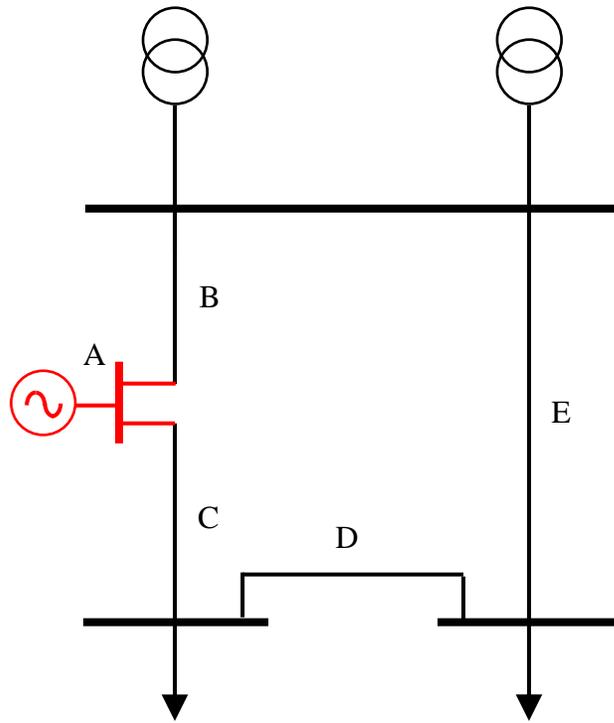


Figure 5, loop in connection on a ring network

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 |

Table 2, East 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 | 185.17 | 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 |

Table 3, East Midlands 33kV Generation Losses Table

| Generation Type | Capacity (MW) | | Selected Cable (mm ²) |
|-----------------|---------------|---------|-----------------------------------|
| | From | Up To | |
| Other | 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 |
| 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 |

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 |
| Wind | 1024.05 | 1024.05+ | 2000 |
| | 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 |

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 |

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 |

Table 7, South West 33kV Generation Losses Table

| Generation Type | Capacity (MW) | | Selected Cable (mm ²) |
|-----------------|---------------|--------|-----------------------------------|
| | From | Up To | |
| Other | 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 |
| 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 |

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 |

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 |

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 |

*300mm² becomes obsolete due to standard price of 400mm²

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 |

Table 12, Wales 33kV Generation Losses Table

| Generation Type | Capacity (MW) | | Selected Cable (mm ²) |
|-----------------|---------------|---------|-----------------------------------|
| | From | Up To | |
| Other | 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 |
| 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 |

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 |

* 300mm² becomes obsolete due to standard price of 400mm²

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 |

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 |

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 |

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 |

Table 18, West Midlands 33kV Generation Losses Table

| Generation Type | Capacity (MW) | | Selected Cable (mm ²) |
|-----------------|---------------|---------|-----------------------------------|
| | From | Up To | |
| Other | 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 |
| 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 |

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 |

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 |

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

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

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

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

5. Calculate total resistance of circuit

$$\text{Total Resistance} = \text{Cable Resistance at } 45^{\circ}\text{C} \times \text{Distance } (\Omega)$$

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

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

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

$$\text{Annual Loss} = \text{Total kWh losses} \times \text{£0.04842}$$

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

$$\text{Loss Saving} = \text{Annual Loss Cable A} - \text{Annual Loss Cable B}$$

11. Calculate the cost of upsizing the cable section

$$\text{Upsizing Cost} = \text{Install Cost Cable B} - \text{Install Cost Cable A}$$

12. Calculate the payback period for upsizing the cable

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

Cable Resistance Calculations

1. The AC resistance at $\theta^\circ\text{C}$, 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:

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

Where,

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

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

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

Where,

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

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.

$$\sum_{t=1}^T \frac{C_t}{(1+r)^t} - C_0$$

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

SUPERSEDED DOCUMENTATION

This document supersedes ST:SD1H dated February 2017 which has now been withdrawn.

APPENDIX E

ASSOCIATED DOCUMENTATION

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

APPENDIX F

KEY WORDS

Losses, Design, Ofgem, CBA, NPV