Capital Project 966

Cable Route Feasibility Report

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EirGrid

CP966

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Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
A	25/11/19	First issue – further data required to complete the report as agreed before issue	NS & GD	ES	NE	FL
B	20/01/2020	First revision, includes EirGrid comments and new Jacobs branding	NS & GD	ES	NE	FL
Final	27/04/2020	Final	NS & GD	ES	NE	FL

Contents

Executive Summary

Capital Project 966 (CP 966) is a proposed development that will help transfer electricity from the west of Ireland and distribute it within the network in Meath, Kildare and Dublin to help meet the growing demand for electricity in that area. This growth is due to increased economic activity and the planned connection of new data centres in the region. CP 966 aims to strengthen the transmission network between Dunstown substation in Kildare and Woodland substation in Meath - and suggests a number of technical solutions to do so.

The connection options being considered by EirGrid are:

Option 1: Up-voltage of the existing 220 kV overhead line (Gorman - Woodland – Dunstown) to a 400kV overhead line;

Option 2: New 400 kV overhead line option; and

Option 3: New 220 kV Underground Cable; and

Option 4: New 400 kV Underground Cable

This report presents the technical feasibility assessment for the two Underground Cable (UGC) circuit options between Dunstown and Woodland substations. The following solutions are analyzed:

- New 220kV circuit (1 conductor per phase) solutions for Option 3
- New 400kV circuit (1 conductor per phase) solutions for Option 4
- New 400kV circuit (2 conductors per phase) solutions for Option 4

In order to effectively complete the work, a number of meetings and teleconferences took place between the Client and Consultants to share information and to determine the contents of the report. A study area was jointly identified to the west of Dublin during the month of October 2019.

A team of specialists were sent, during the month of November 2019, to survey the chosen study area to investigate connection points into substations, ground topology and identify any potential obstacles between the two substations.

This technical report highlights those findings, in respect to the 220kV circuit (1 conductor per phase), 400kV circuit (1 conductor per phase) and 400kV circuit (2 conductors per phase) solutions listed above. It does so by describing the design methodology and construction approach, the advantages of each solution, and their cost in relation to materials only.

This report is to be read in conjunction with:

- 321084AE-REP-001A – Cable ratings compendium
- 321084AE-REP-002 – CP966 Environmental Feasibility Report
- 321084AE-REP-003 – CP966 Social Impact Report
- 321084AE-REP-004 to 321084AE-REP-012 – CP966 Substation Feasibility Report

The report concludes that it is possible to lay cables both at 220kV and 400kV to connect Dunston with Woodland substation, but a number of technical challenges have to be overcome to do so, in particular related to the numerous crossing of both man-made and natural obstacles (river, streams, roads, railways, etc.). The installation techniques used to install the cables and overcome constraints, have environmental impacts which are discussed further in the Step 3 CP966 Environmental Constraints report.

Not all analysed cable solutions will be able to transfer the power delivered by an equivalent Over Head Line (OHL) option. Two routes are required should a 2 conductor per phase solution be selected.

Important note about your report

- The sole purpose of the report is to support EirGrid CP966 project
- Any information relied upon and presumed accurate in preparing the report (i.e. client and/or third party supplied information)
- Ratings calculations have been performed using CYME Cymcap 7.3 rel 2
- Quoted cable prices are subject to materials costs which are subject to change; this report is based on information supplied by EirGrid in December 2019
- Observations and findings in the report subject to the extents permitted by law
- This report shall be read in full with no excerpts to be representative of the findings
- This report has been prepared exclusively for EirGrid Project CP966 Step 3, no liability is accepted for any use or reliance on the report by third parties
- The stated feasibility of the cable route options is subject to the outcome of the substation reactive compensation feasibility report.
- Cable routes presented in the report are for the purpose of feasibility assessment for cable options only. This feasibility is part of EirGrid's Framework for grid development as described by Step 3. Cable route identification to take place in Step 4 if cable solution taken forward. See section 1.2 for more details.

1. Introduction

1.1 What is Capital Project 966?

Capital Project 966 is a proposed development that will help transfer electricity to the east of the country and distribute it within the network in Meath, Kildare and Dublin.

The project will help meet the growing demand for electricity in the east. This growth is due to increased economic activity and the planned connection of new data centres in the region.

A significant number of Ireland's electricity generators are located in the south and south west. This is where many wind farms and some modern conventional generators are located. This power needs to be transported to where it is needed.

The power is mainly transported cross-country on the two existing 400 kV lines from the Moneypoint station in Clare to the Dunstown substation in Kildare and Woodland substation in Meath. Transporting large amounts of electricity on these 400kV lines could cause problems that would affect the security of electricity supply throughout Ireland, particularly if one of the lines is lost unexpectedly.

To solve this emerging issue, we need to strengthen the electricity network between Dunstown and Woodland to avoid capacity and voltage problems.

CP966 aims to strengthen the transmission network between Dunstown and Woodland substations and suggests a number of technical solutions to do so.

1.2 Framework for grid development explained

EirGrid follow a six-step approach when they develop and implement the best performing solution option to any identified transmission network problem. This six-step approach is described in the document 'Have Your Say' published on EirGrid's website 1. The six steps are shown at a high-level in Figure 1. Each step has a distinct purpose with defined deliverables and represents a lifecycle of development from conception through to implementation and energisation.

[1] http://www.eirgridgroup.com/the-grid/have-your-say/

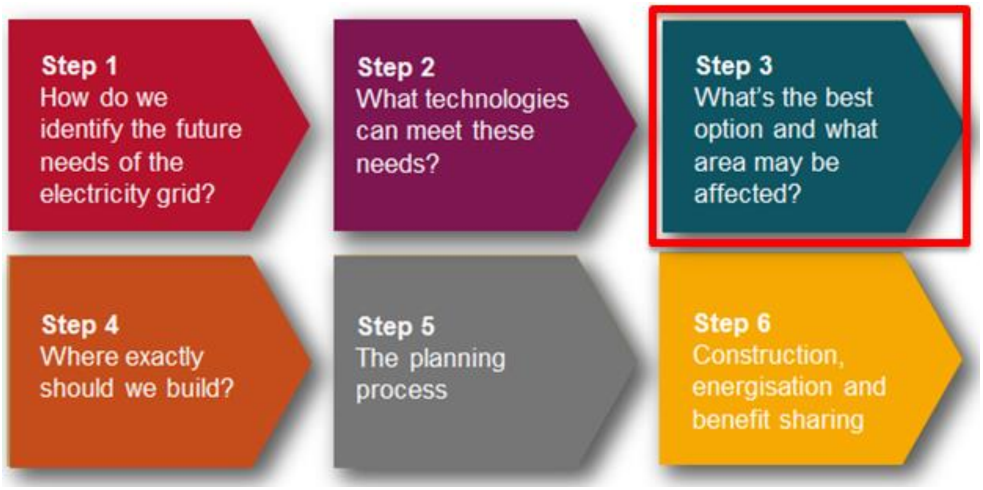


Figure 1 - EirGrid's Six-Step Framework for Grid Development

Capital Project 966 is in Step 3 of the above process. The aim of Step 3 is to identify a best performing solution option to the need identified. There are four remaining technical viable options to be investigated in Step 3. All options create a connection between Woodland and Dunstown substations and have common reinforcements associated in relation to voltage support devices and 110 kV uprates. The main four options are:

- Up-voltage existing 220 kV circuits to 400 kV to create new Dunstown – Woodland 400 kV overhead line (OHL);
- A new 400 kV overhead line;
- A new 220 kV underground cable,
- A new 400 kV underground cable.

Common reinforcements to all four options (outcome of Step 2, may change in Step 3):

- Uprating of the Bracklone – Portlaoise 110 kV overhead line
- Dynamic reactive support device in greater Dublin area rated at approximately ±250 Mvar

These options will be evaluated against five criteria: technical, economic, environmental, deliverability and socio-economic and each criteria incorporates a number of sub-criteria. It shall be noted that the overall assessment is carried out by EirGrid, but certain aspects are investigated and assessed by various consultants and their assessment will feed into the overall assessment.

1.3 Aim and context of this report

This report presents the findings of the investigation of the feasibility of the cable solutions listed below within the study area identified. The finding will feed into the overall evaluation of the four main options including the two OHL options.

This report presents the technical feasibility, deliverability and economic assessment for the two UGC circuit options between Dunstown and Woodland substations listed below. EirGrid (the Client) has engaged Jacobs to assess if feasible underground cable routes can be found within a set study area. The cable options have been specified by EirGrid. The tender reference is SCF17055L1. This report is aimed at presenting the findings of this investigation. The finding will feed into EirGrid's overall evaluation of the four remaining options.

- New 220kV circuit (1 conductor per phase) solution for Option 3

  The option consists of: construction of a new 220 kV underground cable linking Dunstown station to Woodland station. The required rating of the underground cable shall aim to match the rating of a 586 GZTACSR Traonach 210° conductor, with a winter rating of 2377A and summer rating of 2289A.

- New 400kV circuit (1 conductor per phase) solution for Option 4

  The required rating of the underground cable shall match the rating of the existing 400 kV OHL circuits to be comparable with the 400 kV OHL option. The existing 400 kV OHL conductor is 2 x 600 mm^2 ACSR CURLEW at 80°C, with a winter rating of 2963 A and summer rating of 2506 A.

- New 400kV circuit (2 conductors per phase) solution for Option 4

  The required rating of the underground cable shall match the rating of the existing 400 kV OHL circuits to be comparable with the 400 kV OHL option. The existing 400 kV OHL conductor is 2 x 600 mm^2 ACSR CURLEW at 80°C, with a winter rating of 2963 A and summer rating of 2506 A.

This report considers the technical constraints (obstacles) that cable circuits would encounter within the study area through to the connections into the substation's bays. These constraints impact both cable ratings and installation activities. Most of these obstacles would be encountered regardless of the cable route chosen (i.e. Railways, rivers or motorways) Some typical obstacles have been identified and are presented in the report along with indications on how these can be overcome.

To assess the technical feasibility of the options, cable rating calculations have been performed for each of the solutions with cables in the standard trench cross-section arrangement. Where these have not met the required rating, performance enhancing solutions have been suggested (for example including use of backfill with higher thermal conductivity and the widening of the cable trench). A description of the performance of each solution including performance enhancements to reach required ratings has been presented in the report. Additional information and details can be found in 321084AE-REP-001A.

Finally, each of the solutions have been evaluated in terms of their feasibility using the EirGrid coloured scale system, taking some aspects of technical performance and deliverability into account, to give an overview of each option.

It should be noted that the proposed cable solutions are linked/dependent on other technical requirements such as reactive power compensation, alleviation of harmonics issues etc., which are outside the scope of this route feasibility report. It has been therefore assumed that any further technical issue arising from the above mentioned, will be considered elsewhere in the overall assessment of the cable options.

All relevant drawings and specifications are attached as appendices to this report.

1.4 Description of criteria used to assess the options

This report uses the following criteria to assess each cable solutions:

- Technical

  As part of technical feasibility assessment, cable trenches and routes were developed in accordance with relevant EirGrid design standards to indicate a feasible option. Achievable ratings have been calculated using CymCap 7.3 and compared against EirGrid target ratings outlined in SCF17055L1. These ratings as well as proposed cable technology have been used to determine the technical feasibility. Further to this, the constraints encountered on some indicative cable routes have been identified and discussed highlighting issues and solutions.

- Environmental

  Environmental assessment has not been included as part of this report, please refer to report 321084AE-REP-002 – Environmental Feasibility Report

- Deliverability

  As part of deliverability assessment, existing road network, utility networks, as well as man-made and environmental constraints were considered to ensure that the solution can be safely constructed, maintained and operated. The assessment is largely been based on availability of the road network, availability of land to construct, and the amount of excavated material.

- Economic

  An initial bill of quantities (based on logical assumptions) has been prepared for each solution.

- Socio-economic

  Socio-economic assessment has not been included as part of this report. For social impact studies, please refer to the report 321084AE-REP-003 – Social Impact Report.

1.5 Scale used to assess each criteria

The effect on each criteria parameter is presented along a range from “more significant”/”more difficult”/“more risk” to “less significant”/”less difficult”/“less risk”. The following scale is used to illustrate each criteria parameter:

More significant/difficult/risk　　　　Less significant/difficult/risk

In the text this scale is quantified by text for example mid-level/moderate (Dark Green), low-moderate (Green), low (Cream), high-moderate (Blue) or high (Dark Blue).

1.6 Relationship to other technical documents

Parallel to this report, Environmental and a Social Impact studies are being prepared to investigate the impact of proposed cable technologies on the study area.

Please read in conjunction with the following reports;

- 321084AE-REP-002 – CP966 Environmental Constraints Report
- 321084AE-REP-003 – CP966 Social Impact Report
- 321084AE-REP-004 to 321084AE-REP-012 – CP966 Substation Feasibility Reports
- 321084AE-REP-001A Cable ratings compendium

2. The Project

2.1 The study area

The study area is defined as the area investigated for the possible installation of any of the technologies identified by Step 2. The study area has to fulfil a number of criteria to provide a fair investigation into each of the technologies proposed at Step 2.

Figure 2 shows the Project Study Area for CP966. The study area will provide a high likelihood that all technologies considered at Step 3 can be feasibly accommodated within it. The study area identified in Step 2 was used as a basis of the development of a study area. As part of this Step of the project, the Project Study area has been further refined by considering a wide variety of factors. The following were considered when deciding on the extent of the study area:

- Road network presence (easier to route cable via existing roads and for access availability);
- Settlements including villages and towns (settlements require a number of buried services, if the route crosses fewer settlements, the number of services crossed will be reduced);
- Presence of other major services (high pressure gas mains, sewers);
- Existing electrical utilities (mainly presence of existing underground cables);
- Physical constraints e.g. motorway, river or rail crossings;
- Environmental constraints.

By focusing on these issues, in particular the road network and the route length (whereby we are trying to achieve the minimum route length by utilizing existing road network), the study area was selected to give the highest likelihood of ensuring that at least one of the cable technologies would be feasible. The current Project Study Area is smaller than the Step 2 Study Area but is still large enough for the examination of feasible options for the project.

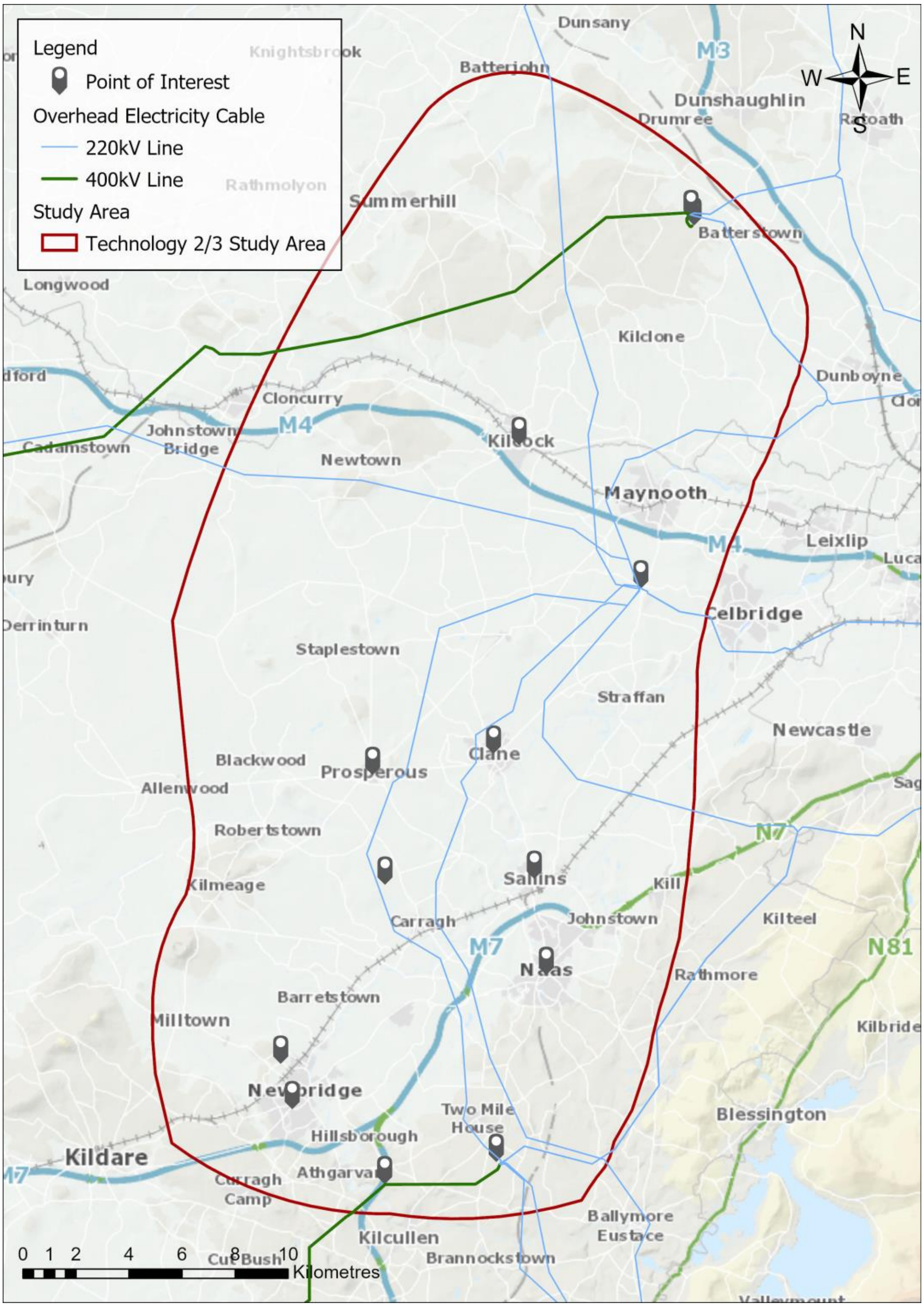


Figure 2 - Final CP996 Study Area for Proposed Transmission reinforcement (red line boundary shows extent of study area)

2.2 Indicative cable routes

Given the study area as per section 2.1 above, and guidelines (provided by EirGrid), two indicative underground cable routes were identified for the feasibility assessment. The constraints (provided by EirGrid) were as follows:

- The route shall avoid motorways;
- The route shall use Ireland's N, R & L roads avoiding congested city centres or industrial estates;
- The use of private land shall be avoided where possible;
- Minimise overall route length as reasonably practicable.

In consideration of the above guidelines, the local geography would allow for the following routes:

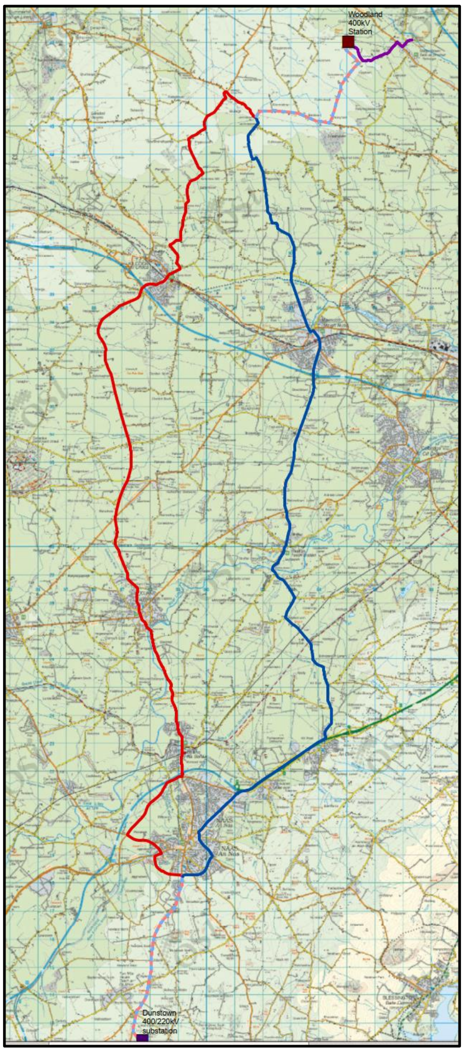


Figure 3 – Outline cable routes for feasibility assessment in red and blue. The purple route around Woodland Substation marks the length of the HVDC East West Interconnector present within the study area.

The routes shown are indicative and have been identified as part of this feasibility exercise where only the existing road network has been used as discussed above. It is noted that the 400kV (2 conductors / phase) solution would have to be routed via both identified routes due to small road size. This is discussed in more detail in later sections. It is anticipated that any final route, due to the various constraints discussed throughout the report, will require the use of third-party land to route the cables. This to avoid "pinch-points" due to existing constraints such as settlements within the study area.

2.3 Key Assumptions

No detailed design work is involved in Step 3 of EirGrid's Framework for Grid Development plan; however, some assumptions are required in order to understand this feasibility assessment:

- Cable ratings calculations, where provided, are based on cable datasheets supplied by EirGrid for both the 220 and 400kV cables (see appendix A). Further to this, the OHL Winter and summer ratings required are as stated in doc no. SCF17055L1 supplied by EirGrid and shown below;
  - One 220kV UGC circuit with a winter rating of 2377A and summer rating of 2289A
  - Two 400kV UGC circuits with a winter rating of 2963A and summer rating of 2506A
  - One 400kV UGC circuit with a winter rating of 2963A and summer rating of 2506A
- For the scope of this work, a maximum conductor cross-section of 2500mm^2 has been assumed which is currently the largest conductor cross section offered by the asset owner.
- A standardised preliminary route length has been assumed for all calculations and to determine the Bill of Quantities (BoQ) for each option. This is the average value, rounded up to the nearest km, of routes 1 & 2 of Figure 3. This length is 50km.
- The number of joint bays along the route has been calculated based on the maximum deliverable length for each cable, as detailed in the supplied cable datasheets.
- The "standard" cable trench cross-sections, for both 220 and 400kV, are based on drawing no. PE424-D7001-001-008-005 supplied by EirGrid (see Figure 16 on p18).
- The standard joint bay dimensions are based on drawing no. PE424-D7001-013-002-000 supplied by EirGrid (attached in Appendix B);
- The solutions envisaged to cross obstacles in this report, are to be considered provisional and based on the limited information available at this stage;

2.4 Study Area Constraints

2.4.1 Route constraints

There are several physical constraints which may limit the implementation of the cable routes directly such as the following:

- Vegetation;
  - Figure 4 and Figure 5 shows a typical country L-road found in the study area. Given the minimum width of the cable trench, the additional space required for the excavated backfill and the access route, it may be difficult to implement a route without damaging the existing vegetation.
  - The presence of tree/hedges roots negatively impacts the thermal resistivity of the existing ground and, therefore, cable ratings, by removing moisture from the soil. In addition, the tree's root systems may get entwined around the cables resulting in physical damage to the cable and later intervention more difficult. CIGRE TB 194 recommends a minimum clearance of 2.5m between the cable and nearby trees. This requirement will need to be clarified in the next stages of the project.
- Heritage sites;
  - Some locations inside the study area may be classed as heritage sites, thus imposing additional constraints on the chosen route. This is discussed within the Step 3 CP966 Environmental Constraints report, please see 321084AE-REP-002.
- Road closures;

- We foresee requiring partial/full road closures for some sections along the possible routes analysed during the site survey. This may have a substantial impact on the community due to limited access to property in the study area. Further investigations will be required.

Both the 220 and 400kV (1 conductor/phase) solutions require a single trench to be installed in the roads however, the 400kV UGC (2 conductors / phase) solution would require 2 cable trenches. As seen from Figure 4 and 5, the L roads, and some smaller R roads, within the study area would be unable to house both cable trenches without the permanent use of third-party land. At this stage in the assessment minimal third-party land is to be used. Therefore, it is considered that the 400kV UGC (2 conductors / phase) option is only feasible by routing the trenches via two different routes. This will lead to more obstacles requiring to be crossed.

Figure 4 - Example of L-Road Constraint in Study Area

Figure 5 - Example of L-Road Constraint in Study Area

2.4.2 Existing infrastructure constraints

Regardless of the route(s) chosen, a number of existing infrastructures will need to be crossed, and a number of constraints will need to be overcome. These crossing will impact the ratings and technical feasibility of all cable route options.

2.4.2.1 Bridges

There are many different bridge types within the proposed study area. These include crossings over National roads, motorways, railways and over bodies of water such as rivers and canals. Since these vary greatly in both size and construction, each solution should be investigated for feasibility

Figure 6 - Example of Bridge Constraint Over National Road in Study Area
(bridge over N7 in Naas, County Kildare, Ireland)

The image shown in Figure 6 is an example of one such crossing over a large National road which may also be representative of a motorway bridge due to its size and structure. Review of the study area for Step 3 shows that in order to lay a cable from Dunstown to Woodland we would need to cross National roads and Motorways for all cable solutions. Use of the motorway network to route new cables has been deemed unfavourable by transport infrastructure Ireland, however a motorway bridge like the one above may provide an option for cable routes crossing the motorways.

In such case one would consider the following:

- Cable trenches installed within the bridge structure itself;
- Cables attached to the underside of a bridge;
- Horizontal Direct Drilling (HDD) under the motorway;
- Finding alternative nearby crossing points where use of the bridge is not possible.

Use of the existing bridges to route cables would require significant additional studies. The following would need to be considered:

- Presence of other services on the bridge;
- Material strength and architectural heritage;
- Structural capacity;
- Temporary works required to install cables into bridge including, but not limited to, erection of temporary scaffolding, temporary lane closures, and traffic management;

Furthermore, it may not be possible to lay the cables in the bridge due to the presence of existing utilities. Each crossing would need to be assessed individually to ensure their feasibility. Figures 7 to 9 show typical crossings over water sources found in the study area. In comparison to Figure 6, these structures are smaller and constructed of different/older brick material which could exclude both burying and clamping options

Figure 7 - Example of Bridge Constraint Over River in Study Area

Figure 8 - Example of Bridge Constraint Over Canal in Study Area

Figure 9 - Example of Bridge Constraint Over Canal in Study Area (County Kildare, Ireland)

2.4.2.2 Canals

Figure 10 - Example of Canal Constraint in Study Area (Sallins, County Kildare, Ireland)

There are many smaller canals, as shown in Figure 10, within the study area.

To route the cable options through small canal bridges is unlikely, alternative solutions will require investigation. Some examples of alternative solutions are shown below:

- Selection of alternative routes/use of 3rd party land;
- Canal crossing using trenching and temporary water over-pumping;
- Using Horizontal Direct Drilling (HDD) technologies;
- Build a stand-alone cable bridge.

2.4.2.3 Rivers

Figure 11 - Example of River Constraint in Study Area (County Kildare, Ireland)

Unlike canals and smaller water sources such as streams, it is very difficult to trench under larger rivers.

Therefore, the crossing options remain the following:

- utilising a nearby bridge;
- utilising trenchless technologies (Horizontal Direction Drills – HDD);
- 3rd party land diversion to avoid river crossing;
- Build a stand-alone cable bridge.

Installation and maintenance costs for this last option are very high. Since the life of a cable circuit can be assumed to be around 40-50 years, any supporting structure would need to be designed for at least the same design life.

Such exposed structures also pose a security risk as there is potential for unauthorised access. In the case in Figure 11 and 12, the visual impact will also need to be evaluated.

Vegetation clearance will be required on the river banks along with environmental and geotechnical studies. Potential impacts on the biodiversity, flora & fauna of the cable options have been discussed in the Step 3 CP966 Environmental Constraints Report.

Figure 12 - Example of River Constraint in Study Area (County Kildare, Ireland)

2.4.2.4 Railways

Figure 13 - Example of Railway Constraint in Study Area (County Kildare, Ireland)

Figure 13 shows a typical railway line encountered often within the project study area. There is a lot of vegetation on either side of the railway which will require clearing and landscaping.

When using HDD to cross below railways tracks, it is important to maintain ground settlement to the minimum to avoid track deformation. This normally requires going deeper underground which in turn causes unwanted derating of the cable.

Standalone cable bridge structures can also be considered with prior agreement from the local rail authority.

Figure 14 Example of Canal and Rail crossing in Study Area

2.4.2.5 Other underground utilities

At time of writing, no detailed information relating to gas, water, sewer or lower voltage cables was made available for the study area.

Jacobs has therefore chosen to utilize own information from other projects in the area.

As is to be expected there a numerous medium/low pressure gas circuits under the residential areas as well as low voltage power supplies.

Due to the size and population density within the study area, it is anticipated that any cable route would cross a significant gas line, or water main and a number of lower voltage electric cables.

There are two main solutions to cross such services:

- divert the existing utility/pipe;
- install the cables underneath/ over the utility;

For both solutions, there is an increased cost for the civil constructions works required. In a scenario where the cable is routed underneath the utility, it is possible that the cable will be significantly de-rated and will not provide the necessary capacity as specified by EirGrid system design.

To reduce the risk of having to cross major services, any cable circuit should be routed to avoid villages/towns/industrial areas where a large number of these services are expected to be.

Figure 15 - Example of Electricity Constraint in Study Area, Underground Cable Entry Point (Naas, County Kildare, Ireland)

Figure 15 shows a 38kV underground cable entry point leading under a main road and provides an insight into some of the electrical utility constraints that any cable technology may encounter within the study area. Electrical interactions between EHV cables and HV cables can lead to de-rating of both cables. Therefore, each cable crossing must be assessed for ratings compliance. This is less of an issue for Low Voltage (LV) cables – cables voltages of 1kV or below. These LV cables are typically used at distribution level for housing. The above example of a 38kV cable would require inspection.

To overcome issues linked to crossing other cables, a deeper trench must be dug underneath the existing infrastructure which will also lead to a re-rated cable. This should be avoided wherever possible.

In the North of the study area is the HVDC "East-West Interconnector" (200kV DC underground cable). This is a nationally significant piece of electrical infrastructure. Any cable route within the study area would need to avoid the interconnector as crossing is not recommended. There are a number of possible routes to access Woodland substation without crossing this cable.

2.5 Cable circuits

2.5.1 Cable ratings in trenches

It is plausible to state that the majority of the cable routes will be in trenches.

There are three key UGC solutions being investigated between Dunstown and Woodland substations:

- 220kV circuit (1 conductor per phase)
- 400kV circuit (1 conductor per phase)
- 400kV circuit (2 conductors per phase)

Cable ratings define how much power can be transmitted via the cable. The higher the rating, the higher its capacity, hence more power can be transmitted. The cable ratings are limited by the cables ability to dissipate heat and relates strongly to its surroundings i.e. materials its buried in (backfill), surrounding soil and depth of buried cables.

It is important to understand how much power can be transmitted by each of the options. If the cable does not meet the required rating, it cannot transmit the required power and will not meet the aims of the project. All ratings calculations have been performed considering the cable system to be “cross-bonded” along the entire route, with balanced minor sections. This is a common sheath arrangement for cables at 220kV and 400kV.

We have initially considered ducts to be unfilled, and all link boxes to be in chambers below ground.

Details of calculations can be found in the report 321084AE-REP-001A Cable ratings Compendium.

As can seen in Figure 16, the standard width of a cable trench, as supplied by Eirgrid, is 1.7m.

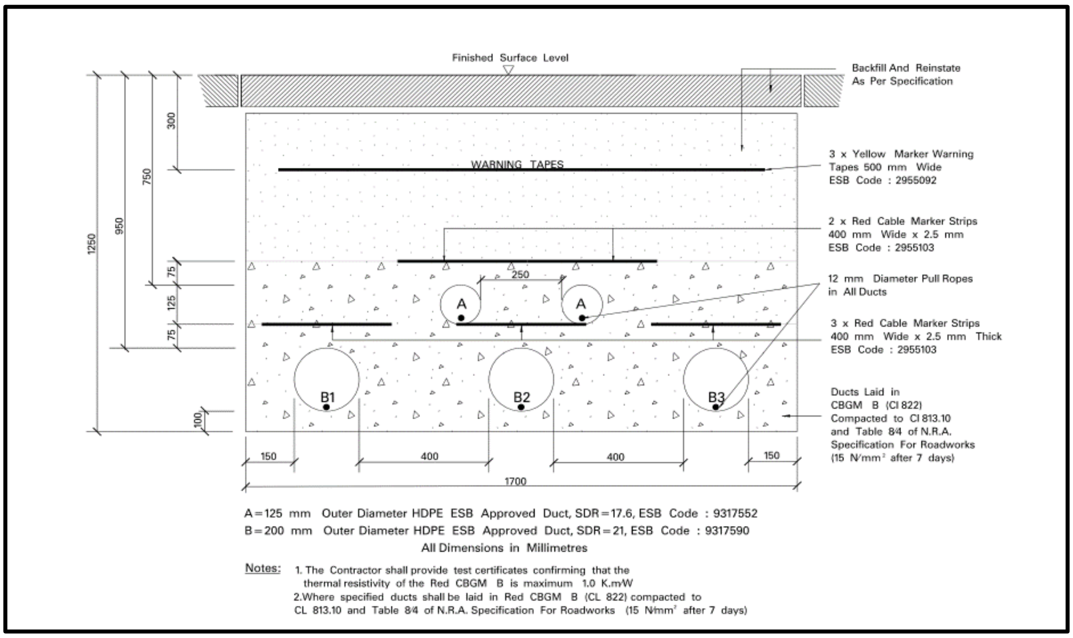


Figure 16 – EirGrid Standard Trench for 220 and 400kV circuits

For the solution that considers 2 conductors per phase at 400kV, it is necessary to consider a separate route for each of the triplets of conductors. This is due to the width of the vast majority of the roads in the study area, which does not allow for two circuits to be placed in the same road. Furthermore, the following factors have been considered:

- most roads already have other buried services (i.e. medium pressure gas, LV electrical)
- the construction requirements
- the need to keep the two-circuit separated to maintain ampacity.

The required cable ratings for each option have been detailed by EirGrid in document SCF17055L1 and are based on the ratings provided by the equivalent 220kV and 400kV OHL. By targeting the ratings of the OHL we ensure that the cable options are fully comparable with the OHL options. These are specified in Table 1 below:

Required Cable Ratings		
Solutions	Winter Rating (A)	Summer Rating (A)
Option 3- 220kV UGC	2377	2289
Option 4- 400kV UGC	2963	2506

Table 1 - Required Cable Ratings per Option

EirGrid are aware that the 400kV UGC (1 conductor/phase) solutions are not able to meet the equivalent rating of the OHL. Thus, a 400kV UGC (2 conductors / phase) solution has been considered to ensure that at least one of the solutions can meet the required ratings.

We have performed ratings calculations under the following conditions:

	Winter	Spring/ Autumn	Summer
Ground Temp. (°C)	10	15	20
Soil Thermal Resistivity (K.m/W)	1.0	1.2	1.2
CGBM Thermal Resistivity (K.m/W)	0.85	1.0	1.0

Table 2 - Cable Rating Calculations Conditions

We have chosen to simulate 3 different temperature scenarios to show how the delivered achievable maximum ratings changes against: the trench width and backfill materials.

EirGrid standard trench and materials (as per Figure 16) provides the following ratings.

Standard Trench					
Solutions	Trench Width (m)	Winter Rating (A)	Spring/Autumn Ratings (A)	Summer Rating (A)	OHL Ratings Met?
220kV UGC	1.7	2220	2038	1968	NO
400kV UGC (1 conductor/phase)	1.7	2119	1937	1867	NO
400kV UGC (2 conductor/phase)	1.7	4238 (2119 x 2)	3874 (1937 x 2)	3734 (1867 x 2)	YES

Table 3 - Maximum Achievable Cable Ratings - Standard 1.7m trench

In order to meet the required OHL ratings from table 1 above, we can try the following:

a) Increase separation between phases, as shown below. We have assumed 1m separation between phases and use of low thermal resistivity backfill material (TR = 0.33 K*m/W).

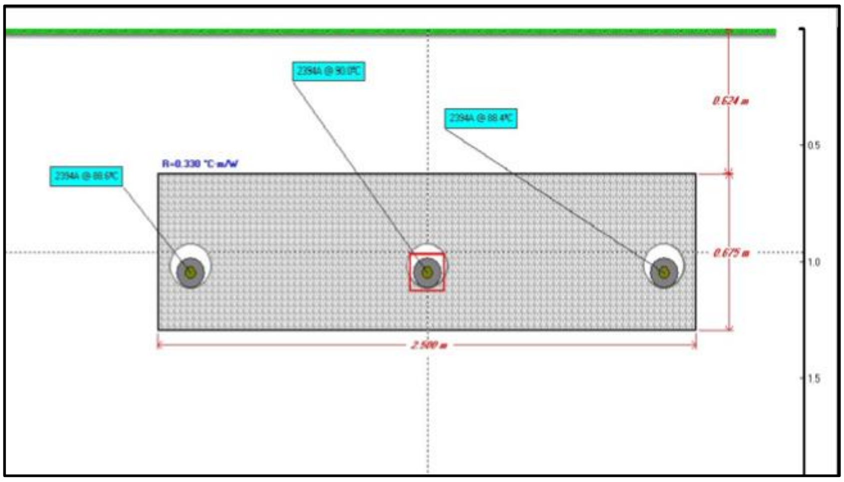


Figure 17 - Increased width trench (2.5m) with low TR backfill

2.5m Trench with Low TR Backfill					
Solutions	Trench Width (m)	Winter Rating (A)	Spring/Autumn Ratings (A)	Summer Rating (A)	OHL Ratings Met?
220kV UGC	2.5	2550	2394	2313	YES
400kV UGC (1 conductor/phase)	2.5	2302	2157	2082	NO
400kV UGC (2 conductor/phase)	2.5	4604 (2302 x 2)	4314 (2157 x 2)	4164 (2082 x 2)	YES

Table 4 - Maximum Achievable Cable Ratings - 2.5m Trench with Low TR Backfill

Figure 17 is indicative only of the dimensions of the low TR backfill and should not be utilized to established final material quantities. A detailed design is required to examine the full extent of the 50°C isotherm and consequentially the quantities of low TR backfill required.

Using the TR backfill and extended trench width, the 220kV UGC cable solution meets the ratings requirement.

The 400kV (1 conductors / phase) does not meet the rating requirement.

b) Increase separation between phases to maximum allowed by carriageway which is shown below. We have assumed 1.5m separation between phases and combined with use of concrete backfill material (TR = 1.0 K*m/W).

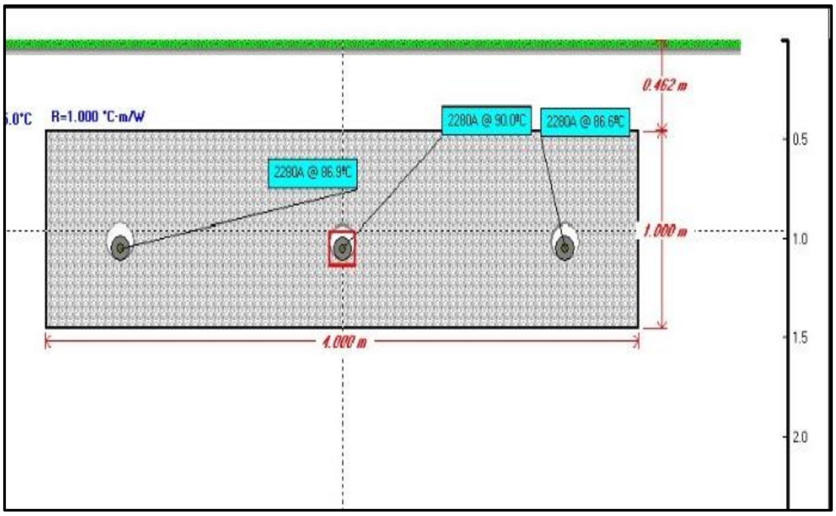


Figure 18 - Road width trench (4.0m) and CGBM backfill

4.0m Trench Width with Concrete Backfill					
Solutions	Trench Width (m)	Winter Rating (A)	Spring/Autumn Ratings (A)	Summer Rating (A)	OHL Ratings Met?
220kV UGC	4.0	2454	2280	2202	96% of summer 100% of winter
400kV UGC (1 conductor/phase)	4.0	2389	2214	2135	NO
400kV UGC (2 conductor/phase)	4.0	4778 (2389 x 2)	4428 (2214 x 2)	4270 (2135 x 2)	YES

Table 5 - Maximum Achievable Cable Ratings - 4.0m Trench Width with CGBM Backfill

Figure 18 is indicative only of the dimensions of the concrete backfill and should not be utilized to established final material quantities. A detailed design is required to examine the full extent of the 50°C isotherm and consequentially the quantities of low TR backfill required.

The 220kV UGC almost meets the ratings at this width. Again, the 400kV (2 conductors per phase) meets the ratings requirement. Whilst trench widening is effective at increasing the achievable ratings of any given cable solution, this has a considerable impact on the deliverability of the solutions. This is discussed further in the deliverability section.

There are a number of additional available solutions to further enhance transfer of power given the constraints of the trench dimensions:

- working with manufacturers to provide “enamelled” conductor solutions, which could provide higher currents given the same conductor cross-section and material
- taking advantage of the possibility to utilise larger conductor cross-section cables (now available up to 3000mm^2 from a number of top tier suppliers)

The above propositions, as well as additional trench dimensions, are investigated in report no. 321084AE-REP-001A – Cable ratings compendium

2.5.2 Crossing with horizontal directional drills (HDD)

In the presence of natural (i.e. rivers) or man-made obstacles (i.e. railways), one of the options is to drill under the obstruction and bury the cable circuits underground. This can be done with a technique known as horizontal directional drilling (HDD). In the case of our survey area, this could be applied in the presence of railway, motorway or river crossings.

By burying the cables deeper in the ground, we decrease the cables ability to dissipate heat, therefore, decreasing its overall rating and causing a pinch point for the entire system.

In order to quantify the performance losses of the cable circuits by using such technique, we have assumed the worst-case scenario to be when the bores are required at a depth of 8m below ground level, with a 5m separation between phases. This could be a conservative choice when crossing below a railway.

The increased depth of burial of the circuits will de-rate the cables as follows:

Cable Derating in HDD			
Solutions	Description	Winter Rating (A)	Summer Rating (A)
220kV UGC (1 conductors/phase)	in 2.5m wide trench with low TR backfill (Figure 17)	2550	2313
220kV UGC (1 conductors/phase)	In HDD as described above	Approx. 20% derating	Approx. 18% derating

Table 6 - Cable Derating in HDD

Data provided in table 6 above is for indication only. The percentage of de-rating of the cables greatly depends on the depth of the drill, the phase spacing and the ground conditions. No consideration has been allowed in this paragraph for the environmental and geological aspects related to HDD drilling. The potential impacts of trenchless technology has been discussed in the Step 3 CP966 Environmental Constraints Report (321084AE-REP-002).

2.5.3 Crossing with cable bridges

Natural or man-made obstacles can also be crossed utilising cable bridges. This solution does not reduce the ampacity of the circuit but comes with a number of drawbacks: for example, it increases the visual impact and the increased risk of damage to the cable systems.

Figure 19 below shows an example of an existing bridge which could serve a dual purpose as both a pedestrian crossing and cable bridge.

Figure 19 - Cable Bridge over Railway

2.5.4 Joint bays

It is not feasible to supply one continuous length of cable to site for the entire route. This is due to the maximum length of cable per drum that can physically be moved to site. Long cable routes (typically above 1 km) require various smaller separate lengths of cable to be delivered (typically between 500-800m at these voltage ranges) and jointed on site to make up the full length of the route. A Joint bay is where any separate lengths of cables are physically joined together. For a typical layout drawing of a joint bay, refer to Figure 20.

Joint bays will be located at regular intervals along the route. The distance between two consecutive joint bays and their exact location is dictated by a number of factors. The following key factors need to be considered:

- Maximum allowed length of cable per drum: assume 740m for a 2500mm^2 220kV cable; and 500m for a 2500mm^2 400kV cable;
- Land constraints along the route: space, accessibility, maintainability etc.;
- Other electrical design constraints (i.e. maximum allowed sheath standing voltages);
- Other installation constraints (i.e. cable pulling).

The size of the joint bays may vary based on the following:

- Local ground conditions;
- Need for additional equipment inside the joint bay (cable monitoring, telecoms etc…).

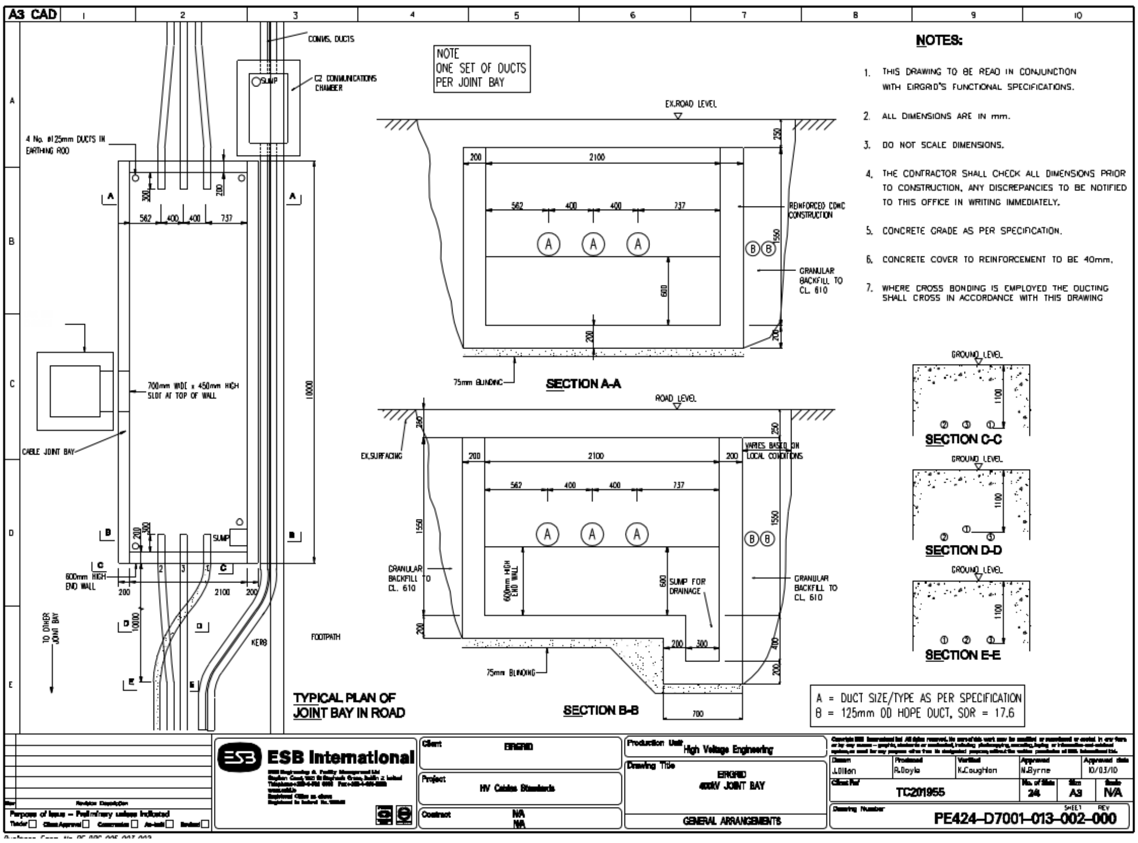


Figure 20 – 400kV Single-Circuit Joint Bay Layout

2.5.5 Connections into substations

The cable circuits will be terminated in Dunstown and Woodland substations where new AIS (Air Insulated Switchgear) bays will be constructed to accommodate the incoming cable connections. A 400kV (1 conductor/phase) cable entry bay and associated reactive compensation at Dunstown substation is shown below in Figure 21 as an example of such connections. All the discussed cable solutions require reactive compensation to mitigate voltage transients during energisation due to the capacitive nature of cable technologies hence compensation has been included.

For more information on these connections, for all Woodland and Dunstown configurations, refer to 321084AE-REP-004 to 321084AE-REP-012 substation feasibility reports.

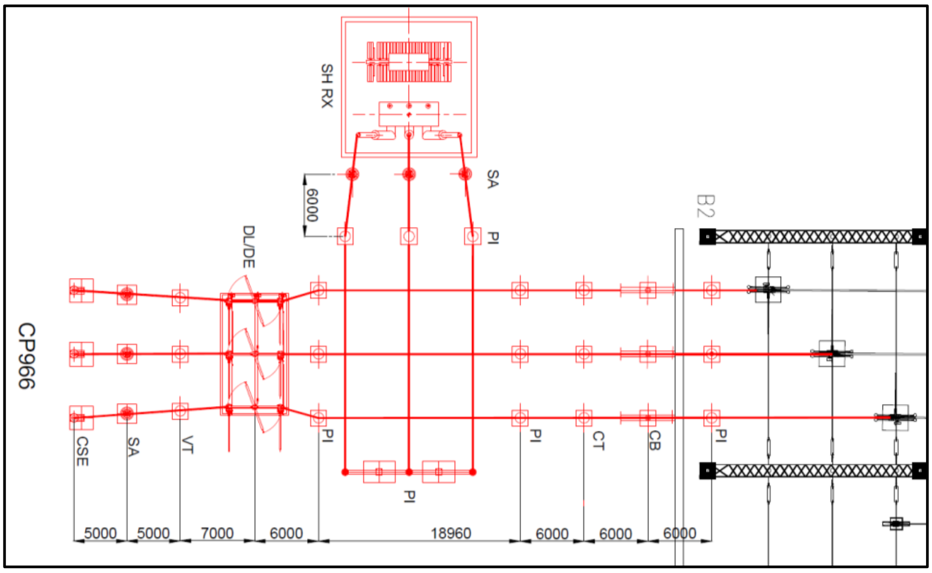


Figure 21 - New Cable Entry Bay Shown in Red

The bays will be within the substation compounds. The footprint of any such bay is not large in comparison to the rest of the substation.

For all solutions, 2 new cable entry bays, 1 at each substation, would need to be provided. Larger bays are required for the 400kV (2 conductors/phase) due to the requirement for double the cable sealing ends (CSE).

There is significant land available within each of the substation compounds, as well as outside along the perimeter. Therefore, it is considered feasible to construct any of the circuit solutions described above and is not considered to be a differentiator for the feasibility of any cable solutions at this stage.

Details of the options considered for new connections at Dunstown and Woodland substations is the subject of separate reports (see 321084AE-REP-004 to 321084AE-REP-012) including the required reactive compensation provided by EirGrid.

2.5.6 Third party land

For any cable solution, third party land use will be necessary. Whether this is for storing of materials and equipment, or for the routing of the cable itself. Where land use is necessary for temporary works, the necessary permissions, payments and wayleaves will need to be obtained from the landowner. Vegetation clearance will be required where 3rd party land is undeveloped

However, there are some advantages to cables being routed through third party land. These are:

- Lower likelihood of encountering other utilities/reduced risk of accidental damage;
- Construction impact on existing road network, and travel disruption caused by works is lowered.

The study area is located in areas Meath, Kildare and Dublin in what is considered a commuter region for the city. As such, there are a number of ongoing housing developments in the area. Any routing of the cable through third party land near settlements could sterilize further land development.

Moreover, if any new scheme is deemed more important than the cable, it could result in EirGrid have to divert the cable at a later stage. Cost and risks associated of diversion would be high and may not be feasible due to EirGrid's responsibility for security of supply.

2.5.7 Technical feasibility

As per Section 1.5, the following scale is used to assess the technical feasibility of this option.

More significant/difficult/risk Less significant/difficult/risk

The 220kV UGC solution meets the rating in a non-standard 2.5m wide trench if specialised low thermal-resistivity backfill is used. However, there are a number of obstacles within the study area suggesting solutions (e.g. HDD) will be necessary. This in turn will affect the achievable current ratings. With this, as well as the non-standard use of specialised thermal backfill, the option is considered feasible but non-standard. This option has therefore been given a moderate level impact on the technical feasibility (Dark Green).

The 400kV UGC (1 conductors / phase) does not meet the rating in any of the above trench scenarios investigated, as well as utilising increased conductor cross-section and therefore technically not feasible. Additionally, there are a number of obstacles within the study area which will require crossing therefore, suggesting solutions such as HDD, which will further de-rate the cable. Taking this into account, this option has been assigned a high-risk technical feasibility rating (Dark Blue).

Further studies in report 321084AE-REP-001A show that it is technically not feasible to achieve the required ratings by further increasing conductors spacing.

The 400kV UGC (2 conductors / phase) cable solution is the only solution which meets the ratings in all scenarios investigated. In addition, as with all the cable options, there are several obstacles within the study area that will need to be crossed requiring solutions such as HDD. This will in turn affect the maximum achievable ratings. However, since it has been assumed that this option will take two different routes, it can be assumed that both of these routes will encounter these obstacles hence, derating problems. Based on the above, this solution has been given a technical feasibility impact rating of high to moderate (Blue).

Cable Solutions	Technical Feasibility
220kV UGC	
400kV UGC (1 conductors/phase)	
400kV UGC (2 conductors/phase)	

Table 7 – Summary of Technical Feasibility

2.6 Deliverability

This section deals with the deliverability of the cable technologies and looks to provide a brief overview of the works required to install any of the cable technologies. As such it focusses on how any of the solutions will be constructed and the key constraints to constructing any cable scheme.

2.6.1 Construction Methodology

There are a few different construction methodologies for laying EHV underground routes, each divided in a number of subcategories.

Trenched

- Ducted cables

  With this method High Density Polyethylene (HDPE) pipes are laid in the trench at the excavation stage and cables are pulled through at a later stage. This allows the de-coupling between civils works and cable installation. This allows for faster construction, reduced time on roadway and the time needed for temporary traffic measures including road closures;

  For the deliverability assessment, it is assumed that the entire route will be fully ducted, since this is the only acceptable methodology employed on cable installations in the Ireland.

  This is in line with the typical cable trench detail provided by EirGrid dwg no. PE424-D7001-001-008-005.

  Delivery of cable drums can be timed to arrive after trench works reducing the amount of land required during construction as well as project traffic on local network at any given time for the duration of the project;

  A typical EHV cable construction employing this method would normally divide the entire route in a number of smaller construction sites each in correspondence with a “major section” of the cable system. Each construction site would remain open only for the duration necessary for the ducts installation and the joint bay preparation. A smaller site would be set up during cable pulling and cable joint activities.

- Direct buried cables

  A direct buried solution is when the cables are buried directly in the soil. Diggers will excavate a specified trench to the required width and depth. The cables are then pulled into place. A selected thermal backfill is poured over the cables. This helps the cables to dissipate heat during operation, improving the achievable rating. Specially selected backfill is then compacted back to ground surface level. This solution requires synchronization of civils works with cable installation.

  This is a non-standard and not acceptable installation method in Ireland.

- Cables in troughs

  Typically used within a substation environment only, normally from the fence boundary to the cable sealing end compound.

  This is a non-standard and not acceptable installation method in Ireland.

Trenchless

- Cables in Horizontal Direct Drill (HDD)

  HDD and deep tunnel boring are expensive methodologies, requiring the use of specialist equipment, and are typically used in special circumstances only. HDD may be used to cross specific obstacles within the study area, such as rivers, for short lengths of the cable route.

  This is the only acceptable and standard methodology employed in Ireland.

- Cables in deep bore tunnel may be used for short sections when traditional horizontal directional drilling techniques would de-rate the cable circuits excessively. This is a non-standard solution in Ireland
- Cables in Pipe Jacked solutions / Micro tunnels. This is a non-standard solution in Ireland

Other

- Bespoke cable bridges, often serving a dual purpose for both pedestrians and services, can be used to divert cable routes around constraints where other solutions are not suitable.

2.6.2 Temporary Working Strip

A temporary working strip is defined as the area of land required, a cable corridor, for the construction of EHV underground cable transmission lines. This is far larger than the width of the trench alone as there will be various ongoing construction activities within the temporary working strip:

- Storage of equipment, and materials;
- Storage of the excavated topsoil and subsoil;
- Delivery of cable drums to site;
- Excavation of the cable trench;
- Cable drums and accessories deliveries;
- Excavation equipment deliveries;
- Jointing equipment and wellbeing facilities deliveries and removal;
- Specialized backfills deliveries;
- Waste removal;
- Staff ingress/egress from site.

Figure 22 shows an indicative temporary working strip which could be put in place for the installation of the three cable solutions. For the purposes of the Step 3 study, it is estimated that the swathe could be 12m, both for the 220kV and 400kV single conductor per phase options. The widths used are based on a worst-case construction methodology where the construction materials and vehicles are offline (to the side of) the cable ducts. There are more space efficient installation techniques utilising machines excavating and pouring the concrete for the ducts online (i.e. machines working along the “lane close” shown in Figure 22). Additional machinery can be used to remove the spoil at the same time. This reduces the land required for the temporary working strip.

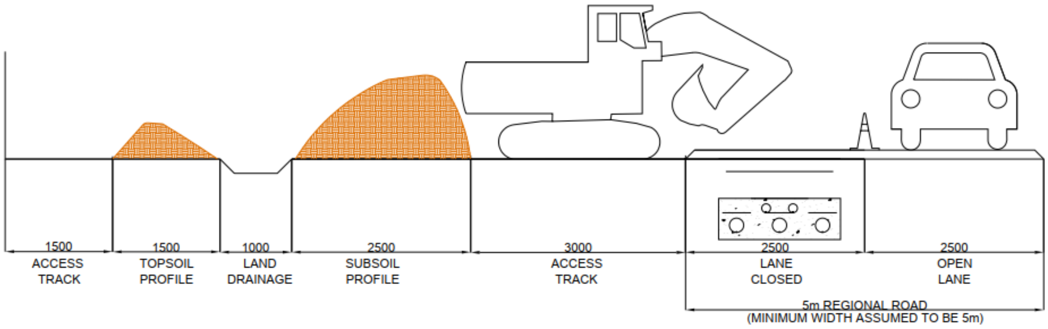


Figure 22 – Indicative Temporary Working Strip

The working strip will vary throughout the study area depending on local constraints to the installation of the cable. In some stretches it will not be possible to accommodate a 12m width. In these instances, a more space efficient installation technique can be used such as the described technique in the previous paragraph. Within the study area we will most likely be burying cables under the Local (L roads); Regional (R roads); and National (N roads).

The worst-case scenario is the 400kV UGC (2 conductors per phase) along one route which would require two 400kV cable trenches in parallel. The temporary working strip to accommodate is assumed as double the indicative for the 400kV single conductor per phase: 24m. This would be far greater than the available road space and has been considered infeasible. Instead this option would require the cable to be routed via. two different routes. Hence the assessment has considered the 400kV two conductors per phase option as using both indicative routes.

For narrow roads, farmland within the study area could be used for the cable routes. However, the larger the working strip the higher the cost of the project. The necessary easements and wayleaves would be required before works could be started.

2.6.3 Easement and Wayleaves

It is expected that large amounts of third-party land are required for the installation of the cable options. The easement is defined as “the use of someone else’s property or land for a stated reason”. A wayleave is defined as “access to property granted by a landowner in return of payment”. The need for these is common for any utility being installed and maintained.

The use of third-party land would require wayleaves to be agreed with the landowner in exchange for payment. The more land used, the more money the landowner will need to be paid. Therefore, we can observe the following:

- The 400kV (2 conductors per phase) option requiring a larger working strip will be more costly than either of the single circuit solutions;
- The 220kV and 400kV single circuit solutions will incur similar costs for third party land use.

Use of third-party land for these types of projects is not unusual however, due to the anticipated road sizes, there may be more of a reliance on this land than other cable projects.

2.6.4 Excavated materials

Whilst the cost of third-party land use will have a significant impact on the cable solutions choice, there are other economic and technical issues to be considered.

Most notably, the construction materials required, and their storage and disposal.

Of these, the excavated soil will likely pose the highest cost as its storage has a significant footprint on the working strip. For our smallest trench size (220kV single circuit), over an assumed cable route length of 50km, roughly 143,375 m^3 of soil will be excavated.

Some of the excavated soil could be repurposed, however most of the excavated soil will have to go to spoil. This will be achieved by using HGVs to truck the soil from site to predetermined disposal sites. The more soil excavated, the more soil to be disposed, the more HGVs you need and the higher the construction cost.

Furthermore, this will add to the construction traffic on the existing road network causing congestion around sites.

The storing and disposal of excavated material will be a significant factor in the cost of the project. The 400kV solution (2 conductors per phase) requires two separate trenches and will result in the highest amount of excavated soil. This will have high construction costs and deliverability impact if compared to the single circuit solutions.

2.6.5 Fill

All excavations will have to be backfilled to road level after cable duct installation. In ducted construction, two materials are used for the fill: Cement Bound Granular Mixtures (GBGM); and engineered fill. After the ducts are installed the CGBM is poured to surround the ducts to a calculated level. This level depends on the thermal dissipation required to meet the ratings. CBGM has a lower thermal resistivity than native soil and so conducts heat away from the cables more efficiently. However, the pouring CBGM to ground level is not cost effective. Instead trenches are designed with enough CBGM to achieve ratings and then use engineered fill to ground level. In some scenarios, specialised thermal backfill will be used instead of CBGM to give a lower thermal resistivity, improving the rating performance of the cables, as investigated in Section 2.5.1.

For the purpose of this assessment a simplified calculation has been adopted to estimate the volume of fill. Table 8 presents the estimated fill for each trench size considered in Section 2.5.1:

Trench Size	CBGM (m^3)	Specialised thermal backfill (m^3)	Engineered Fill (m^3)	Total Fill (m^3)
Standard Trench – 1.7m	86000	N/A	57375	143375
Wide Trench - 2.5m	N/A	152000	84375	236375
Wide Trench - 4m	150000	N/A	101250	251250
2 X Standard Trench	172000	N/A	114750	286750

Note 1: All trenches use CBGM except "Wide Trench – 2.5m" which uses a specialised thermal backfill as per Section 2.5.1;
Note 2: A correction coefficient has been introduced for the CBGM and specialised thermal backfill volume. This coefficient has been introduced to estimate the additional amount of specialised backfill required to fully encompass the 50°C isotherm as a detailed ratings calculations would do, as opposed to the quantity described by the preliminary ratings calculations supplied with this document;
Note 3: All values calculated using assumed route length of 50km.

Table 8 – Estimated fill required against trench size

By inspection the 220kV and 400kV (single conductor per phase) options will require the same amount of fill as one same size trench is used for both options. The 400kV (2 conductors per phase) will require a larger amount of fill as we need to provide two trenches as opposed to one. If a wider trench size is progressed for either the 220kV or 400kV (single conductor per phase) more fill would be required. However, the 400kV (2 conductors per phase option), requiring two trenches, still requires the largest amount of fill.

The fill will need to be delivered to site having additional impacts to the cost of the project as well as the amount of construction traffic on the road network. In the assumed methodology, the fill would be delivered to site in a truck and poured directly into the trench. Alternatively, if the trench is not complete before delivery, the fill will need to be stored in a temporary storage area. The delivery of fill, requirement for temporary storage and construction methodology are project specific. Details to be confirmed at a later stage in the project if a cable option is progressed.

2.6.6 Impacts on the existing road network

The cable technologies are to be primarily routed via the existing road network within the study area. This will have a significant impact on the delivery of the project.

The study area has a relatively dense road network that makes some of its more remote areas more accessible, as well as the larger N and M roads making it easier to deliver materials to site. Construction deliveries will have to be planned to reduce the amount of construction traffic present on road networks as much as reasonably possible.

For the smaller R and L roads it is possible that abnormal load assessments will be required for the delivery routes to ensure the heavier construction materials, such as the cable drums, can be delivered to site without damaging existing roads and structures.

Traffic management will also play a key part in project deliverability as the cables are likely to be buried for large sections under the existing road network hence, requiring road closures to facilitate the work.

It is assumed that many of the R roads are wide enough to allow a single trench under one of the lanes. This would result in a lane closure for the installation. This has significant Health and Safety implications for construction workers. Workers will be working next to live traffic. Whilst this is not unusual in the construction industry it does raise the risk profile of any cable technology being installed within the study area.

The L roads within the study area are small and a full road closure will likely be required where the cables are routed under these roads.

These challenges are typically faced by any cable project and do not impact overall feasibility.

2.6.7 Deliverability feasibility

As per Section 1.5, the following scale is used to assess the deliverability feasibility of this option.

More significant/difficult/risk Less significant/difficult/risk

The 220kV UGC and 400kV UGC (1 conductor /phase) will have similar implications for deliverability as both involve the installation of a single trench along 1 route. The impact on deliverability, is the availability and size of the existing roads and the number of obstacles encountered (canals, railways, brides), that will require additional civil works to overcome such as HDD, utilising existing structures, or specialised cable bridges.

Many of the roads within the study area are L and R roads. The size of these roads means that much of the route may have to be installed using more space efficient techniques to facilitate an online build as opposed to the installation technique shown in Figure 22. Alternatively, additional lane closure or temporary use of third-party land may be required. Furthermore, any lane closures will require traffic management as well as additional H&S planning to mitigate the hazards posed by working next to live traffic. This does not necessarily differ greatly from any typical cable scheme involving roadways.

Also, the study area contains towns such as Maynooth and Naas which will be supported by an active network of utilities including water, gas and electricity. These networks will be primarily routed via the existing road network.

Diversions or crossings are therefore anticipated for all cable solutions where the more utilities in the area, the increase in construction required to deliver the project.

Furthermore, the movement of spoil from site will generate a significant amount of construction traffic. This can be mitigated somewhat through phased construction of the cable trench. This can lead to local congestion to the works

Taking the above into account, with the current constraints present within the study area, it is thought that the install of 50km of cables using the existing road network is feasible but difficult. Whilst all the above is typical of any cable project, the number of constraints and works required to install is considered to be more significant than the typical transmission project. Therefore, the 220kV UGC and 400kV UGC (1 conductor per phase) solution have been considered to have a high to moderate impact on deliverability (Blue).

The 400kV UGC (2 conductors / phase) with the routing of two trenches via two separate routes doubles the amount of work proposed in the installing of one trench. With two routes and cables, we are doubling the materials being used, the material being excavated, and the construction traffic required. The land required and obstacles to be crossed is also increased. Taking the above into account, the impact associated with the deliverability of this solution is considered to be higher than the previous cable solutions and is considered to have a high impact on deliverability aspects (Dark Blue).

Solutions	Deliverability Feasibility
220kV UGC	
400kV UGC (1 conductors/phase)	
400kV UGC (2 conductors/phase)	

Table 9 – Summary of Deliverability Feasibility

2.7 Material quantities

2.7.1 Assumptions

Project quantities is based on the following assumptions:

- The route distance between Dunstown and Woodland substations to be 50km.
  This has been determined Cable routes as per outline in figure 3. Further details in paragraph 2.2.
- The conductor cross-section and material are assumed constant along the entire route:
  there are no conductor cross-section changes required for special crossings etc.
- The number of joint bays has been calculated using the maximum delivery lengths as per in the supplied cable datasheets
- We have assumed 3 river crossings, 1 railway crossing and 1 motorway crossing for each route

2.7.2 Materials quantities

Material Quantities			
220kV UGC (1 conductor / phase)			
220kV route length	50	km	150km in total
245kV Joints	204	Units	23 major sections and 69 minor sections of 725m.
245kV Terminations	6	Units	
Cross bonding /direct earthing link boxes	70	Units	46 cross-bonding boxes 24 direct earth link boxes
400kV UGC (1 conductor / phase)			
400kV route length (1c/phase)	50	km	150km in total
400kV Joints (1 conductor/phase)	303	Units	34 major sections and 102 minor sections of 490m.
400kV Terminations	6	Units	
Cross bonding /direct earthing link boxes	103	Units	
400kV UGC (2 conductor / phase)			
400kV route length (2c/phase)	100	km	300km in total
400kV Joints (2 conductors/phase)	606	Units	34 major sections and 102 minor sections of 490m, for each circuit
400kV Terminations	12	Units	
Cross bonding /direct earthing link boxes	206	Units	

Table 10 - CP966 Material Quantities

2.7.3 Economic feasibility (a high-level approach)

As per Section 1.5, the following scale is used to assess the economic feasibility of this option.

More significant/difficult/risk Less significant/difficult/risk

The high number of obstacles in the study area introduces significant works to the UGC schemes and therefore poses a significant risk regarding its economic feasibility for all solutions. These incurred costs will include those for cable bridges and/or HDD solutions throughout the study area.

From Table 9 above, its noted that the 220kV UGC option will require 150km of cable (50km for each phase), 204 joints, 6 terminations and 70 cross bonding/earthing boxes. Further to this, this UGC solution will require a specialised low-thermal resistivity backfill in order to reach the required ratings (also see report 321084AE-REP-001A). Due to the number of obstacles and the potential additional costs associated with the non-standard approach to meet ratings requirements, this option has been considered to have a high to moderate impact rating (Blue).

The 400kV UGC (1 conductor/phase) option, according to Table 9, will require the same length of cable (150km) hence, the same number of solutions to constraints encountered within the study area can be assumed.

There may be differences in the costs associated with the cable itself, however such costs are undefined at this stage of the project. There will be the need for 303 joints and 103 cross bonding/earthing boxes which will increase the costs of this UGC option when compared to the 220kV option (additional 99 joints and 33 cross bonding/earthing boxes). With the extra requirement for equipment and construction/labour costs for this, the impact of this UGC option has been assumed the same as that as the non-standard 220kV solution and given a high to moderate rating (Blue).

Lastly, the 400kV UGC (2 conductors/phase) option will require double the amount of physical cable when compared to the other available solutions (300km). This extra distance will increase both the costs linked to solutions to constraints (HDD, cable bridge) and the amount of cable itself. This will also further increase the amount of required equipment in the circuit to 606 joints, 12 terminations and 206 cross bonding/earthing boxes. With this, and the associated construction and labour, it can be assumed that this option will be significantly more than the previous UGC solutions. This has therefore been given an impact rating of high risk (Dark Blue)

Solutions	Economic Feasibility
220kV UGC	
400kV UGC (1 conductors/phase)	
400kV UGC (2 conductors/phase)	

Table 11 - Summary of Economic Feasibility

3. Conclusion

3.1 Combined Feasibility

As per section 1.5., the concluding assessment of the presented cable solutions have been rated using the colour coding illustrated below where it ranges from high risk (dark blue) to low risk (cream). High-moderate to low-moderate risks have been represented by blue, dark green and green, respectively.

More significant/difficult/risk Less significant/difficult/risk

Solutions	Technical Feasibility	Deliverability Feasibility	Economic Feasibility	Combined Feasibility
220kV UGC				
400kV UGC (1 conductor/phase)				
400kV UGC (2 conductors/phase)				

Table 12 - Cable Option Assessment Overview

The 220kV UGC option meets the required current ratings compared to those of the targeted OHL ratings however, this is done through the non-standard means of a larger trench and specialised low thermal resistivity backfill (section 2.4). Difficulties overcoming the number of common cable route constraints found across the 50km indicative route (section 2.5) and typical issues regarding deliverability with respects to construction and works in cable projects like CP966 (section 2.6) increase the overall feasibility impact of this cable option. Lastly, the high costs expected for a cable route of this length (section 2.7) is also rated at high risk. This gives the overall feasibility rating of high to moderate (Blue)

The 400kV UGC (1 conductor/phase) circuit option did not meet the current rating values in any of the calculations (section 2.4) which ranks its technical feasibility at high risk despite it only being one set of conductors i.e. one route. This option, similarly to the above 220kV UGC option above, did improve slightly in respect to deliverability and costs due to the use of only one set of conductors (section 2.6 and 2.7). This however does not mean that they can be assumed low risk and therefore is still given a high to moderate impact rating on its overall feasibility (Blue).

The 400kV (2 conductors/phase) circuit option has met all the required ratings throughout the calculations (section 2.4), it still arrives at a high-risk rating for technical feasibility due to the need for double the infrastructure (section 2.5). Further to this, the deliverability and economic impact (section 2.6 and 2.7, respectively) are rated at high risk due to the associated materials, construction and costs associated with two separate cable routes.

Appendix A. Cable Data Sheet

nkt cables

nkt document no. TDA 330 Rev. 2 / 13.03.2017
1 x 2500Cu XLPE Al PE 400 kV

TECHNICAL SCHEDULE TS – 56

400 kV XLPE Land Cable – 2,500mm² Cu XLPE

Physical Characteristics

Note: All dimensions to be filled in where applicable.

Item	Query	Unit	Reply
1	Conductor:		
	(a) Material Grade		copper
	(b) Type e.g. round, etc.		round
	(c) Design e.g. stranded, segmental, enamelled etc.		stranded, segmental
	(d) Nominal diameter	mm	63
	(e) Cross-sectional area	mm^2	2500
	(f) Method of water blocking		swelling yarns and/or swelling tapes
2	Inner Semi-conducting Layer:		
	(a) Material Grade		XLPE
	(b) Nominal thickness	mm	1,8
	(c) Minimum thickness	mm	0,7
3	Insulation:		
	(a) Material Grade		XLPE
	(b) Nominal thickness	mm	26,2
	(c) Minimum thickness	mm	23,6
	(d) Ovality of insulation ≤ 10%		≤ 10%
4	Outer Semi-conducting Layer:		
	(a) Material Grade		
	(b) Thickness	mm	1,5
	(c) Minimum thickness	mm	0,7
5	Nominal diameter over core screen	mm	123
	Roundness of core ; maximum ovality < 0.9mm	mm	max. 0,9
6	Radial thickness of insulation incl. semi-conducting layers		
	(a) Nominal	mm	29,5
	(b) Minimum	mm	25,0
7	Bedding Layer/Water Barrier		
	(a) Material		semiconducting and swellable tapes
	(b) Thickness	mm	2,5
	(c) OD of bedding layer	mm	128
	(d) Method of electrical connection between 4 and 8 to avoid discharges		semiconducting and swellable tapes
	(e) Method of water blocking		semiconducting and swellable tapes
8	Metallic Sheath:		
	(a) Material		aluminium
	(b) Type, corrugated or smooth		smooth
	(c) Nominal thickness	mm	1,5
	(d) Mean diameter	mm	129
	(e) Cross-sectional area	mm^2	608
	(f) Diameter over crest of corrugations	mm	n. a.
	(g) OD of sheath if not corrugated	mm	131
	(h) Diameter and no. of extra copper wires required to ensure short circuit performance of cable meets Specification 18080 (if needed)		n. a.
9	Outer HDPE/MDPE Sheath :		
	(a) Material		HD PE
	(b) Nominal thickness	mm	5,0
	(c) Minimum thickness	mm	4,15
	(d) Shore D hardness		appr. 58

Figure 23 - 400kV cable datasheet

nkt cables

XLPE insulated Cable 220 kV 1x 2500 Cu
nkt offer 23829
ESB specification 18090

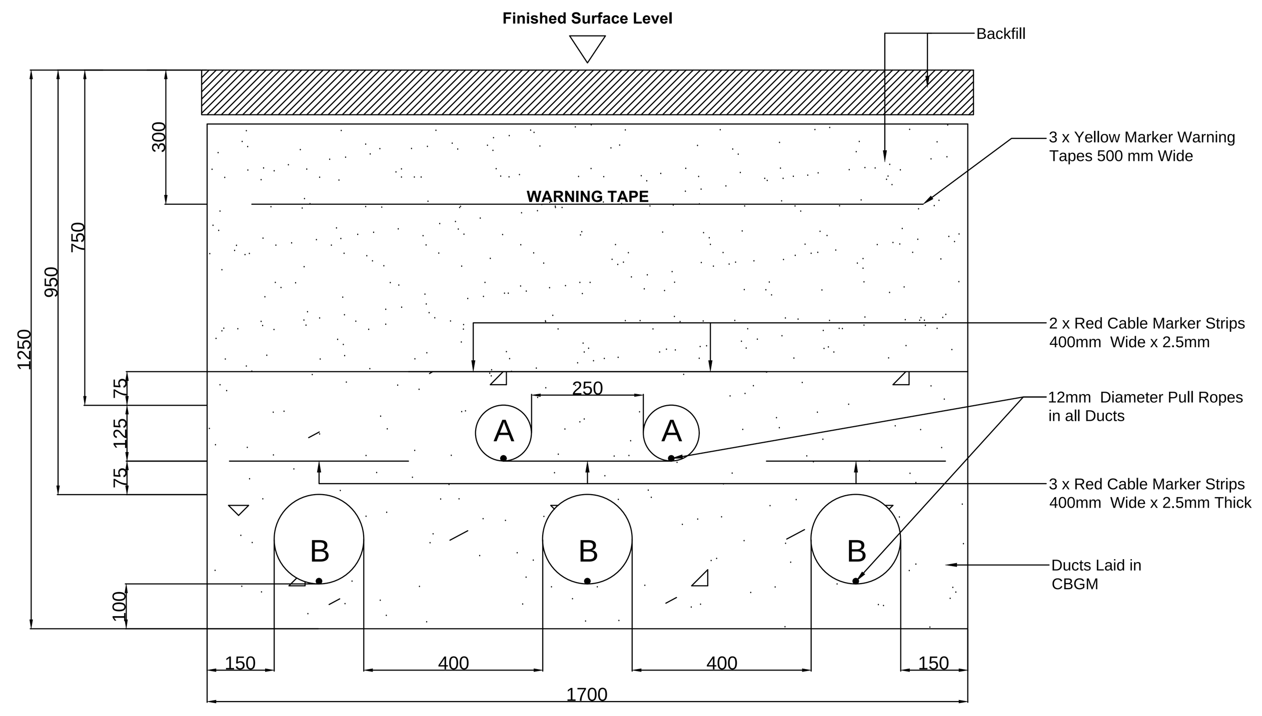
SCHEDULE A (continued)
Physical Characteristics of 220kV Crosslinked Polyethylene Cable

Item	Query	Reply
9	Corrosion Protection:	
	(a) Material	PE
	(b) Nominal thickness — mm	4,9
	(c) Minimum thickness — mm	4,07
	(d) Shore D hardness — approx.	58
	Height of marking with indented lettersby laser marking on the cable sheath — mm	appr. 10
	marking text 1st line: ELECTRIC CABLE 220000 V 1x2500/150 CU/XLPE/CU-PB/PE nkt cables <year> ESB <metre marking (4 digits)> 2nd line: <code number (4 digits)>	
10	Nominal diameter of completed cable — mm	135
11	Nominal weight of finished cable — kg/m	44
12	(a) Normal length per drum — m	740
	(b) Maximum length per drum — m	to be agreed upon
13	(a) Normal gross weight of loaded drum — approx. kg	36
	(b) Maximum gross weight of loaded drum — approx. kg	to be agreed upon
14	(a) Normal drum dimensions width/height — approx. m/m	3,2 /4,3
	(b) Maximum drum dimensions width/height — approx. m/m	3,7 /4,3
15	Minimum radius of bend around which cable can be pulled — m	3,4
	(a) Laid direct — m	3,4
	(b) In ducts — m	3,4
	(c) Cable placed in position with former — m	2,0
	(d) Cable placed in position without former — m	3,4
16	Permissible pulling force allowed on conductors during installation — kN	125
17	Maximum permissible sidewall forces — kN/m	10

Figure 24 - 220kV cable datasheet

Appendix B. Trench Cross-Sections

See "Appendix B - Cable Trench Drawing" PDF in file.

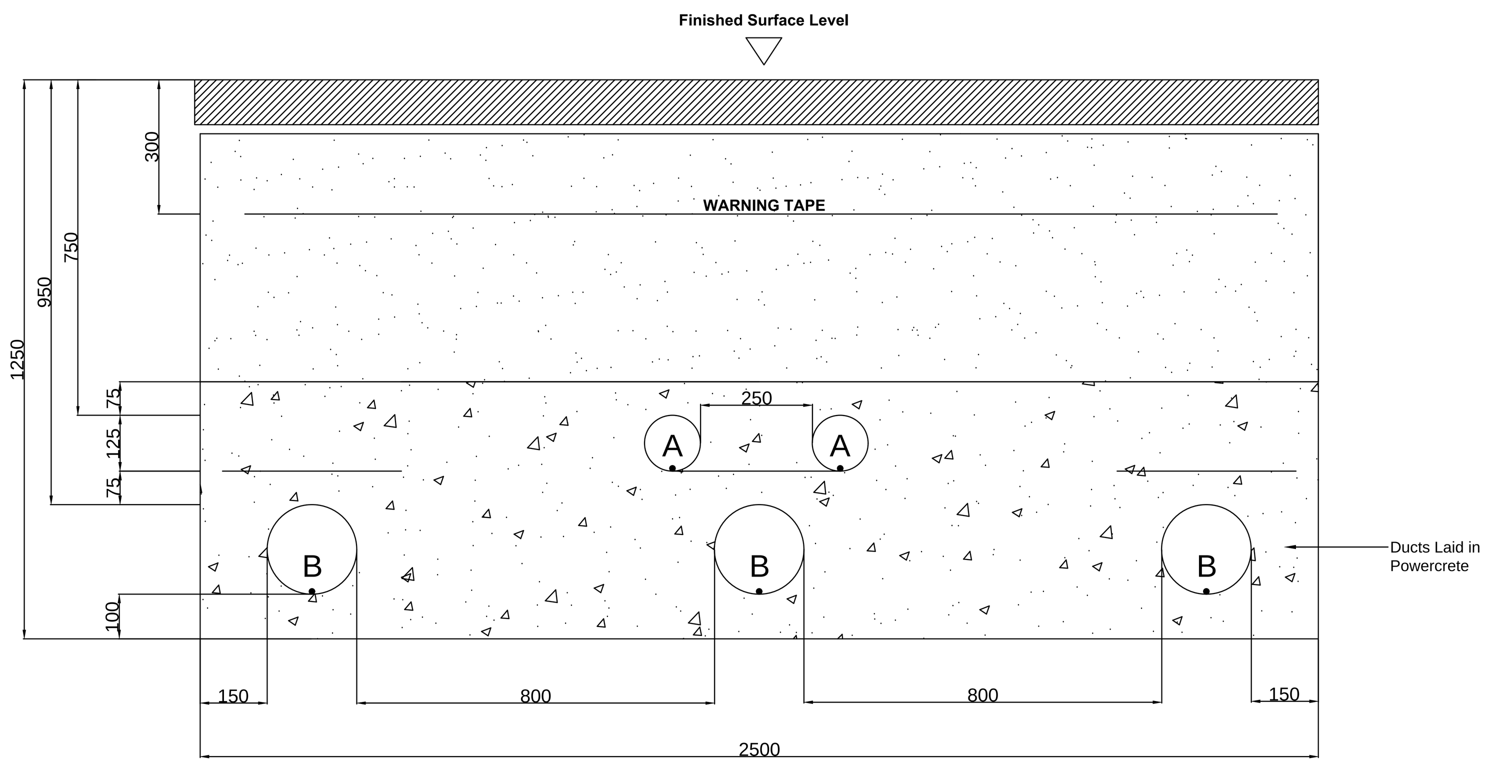


A = 125mm Outer Diamter HDPE

B = 200mm Outer Diameter HDPE

STANDARD 220kV or 400 kV (1 CONDUCTOR / PHASE) TRENCH LAYOUT

SCALE 1:10

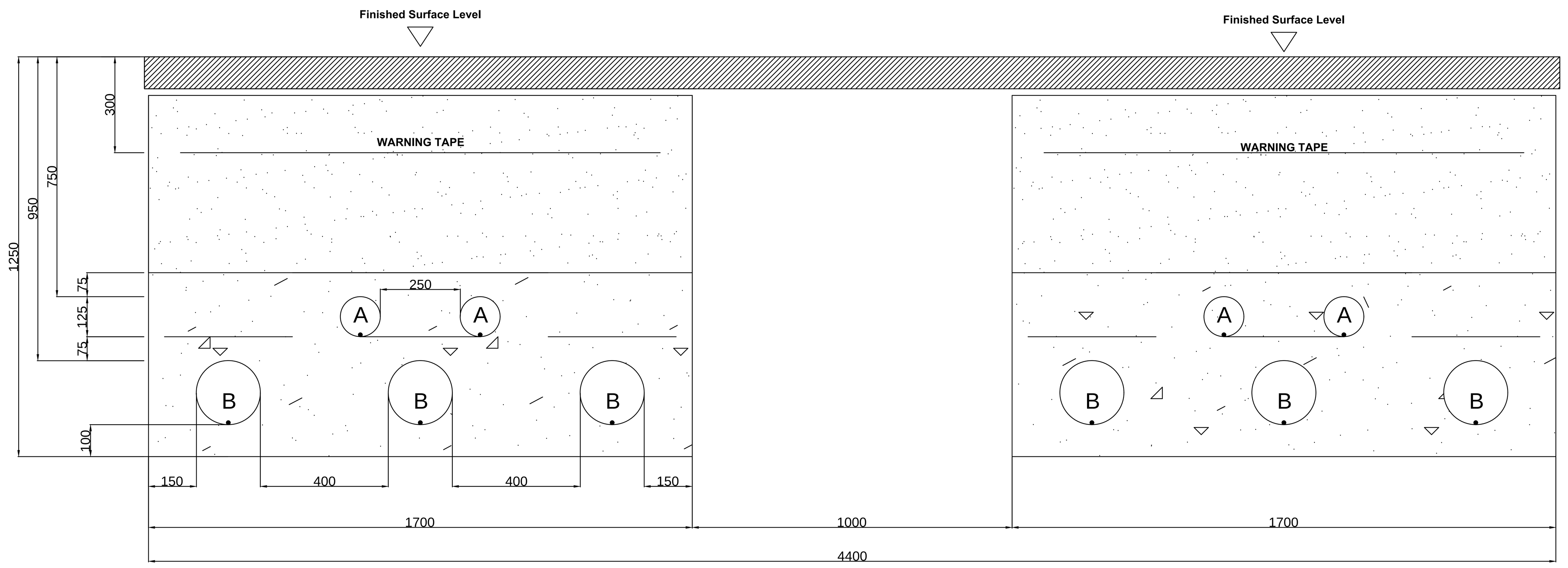


A = 125mm Outer Diamter HDPE

B = 200mm Outer Diameter HDPE

220kV OR 400kV (1 CONDUCTOR / PHASE) WIDE TRENCH LAYOUT WITH POWERCRETE

SCALE 1:10



A = 125mm Outer Diamter HDPE

B = 200mm Outer Diameter HDPE

STANDARD 400kV (2 CONDUCTORS / PHASE) TRENCH LAYOUT

SCALE 1:10

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
01	17.01.20	ISSUE FOR INFORMATION	GD	NS	ES	FL
00	25.11.19	DRAFT	SJ	GD	ES	FL

NOTES

1. This drawing is for development purposes.
2. Cable trench details are based on simulations in CYMCAP for provided typical cables. Final cable trench details will change depending on selected technology and cable type.
3. For details on ratings, see report 321084AE-REP-001.

LEGEND

- Tape
- Powercrete
- Concrete
- Compacted back fill

REFERENCE DRAWINGS

TRENCH CROSS SECTION FOR 2500mm^2 Cu CABLE DUCTED INSULATION PE424-D7001-013-002-000

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Client: EIRGRID

Project: EIRGRID CP966

Drawing title: INDICATIVE CABLE TRENCH

Drawing status: ISSUE FOR INFORMATION

Scale: @ A0 — DO NOT SCALE

Jacobs No.: 321084AE-LAY-001

Client no.:

Rev: 01

Drawing number: 321084AE-LAY-001

P:\Energy\EirGrid\321084AE - EirGrid CP966\03 Drawings\3.2 Current\321084AE-LAY-001_01.dwg - 17/01/2020 10:34:03 - Layout3-A0Frame - DunlopG

Appendix C. Cable Ratings Calculations

Cable ratings calculations have been supplied as appendices to report 321084AE-REP-001A.