

TECHNICAL NOTE 02



Project: Carrownagowan Wind Farm – 110kV Grid Connection	Ref: Rev01
Section: Underground Cable Ampacity Study	Job No: 05-641
	Date: 19.05.23
Made By: JVDP	Checked By: DB
	Sheet No: 1 of 22

Instruction

Technical Lead: Damien Browne (TLI Group)

Date of Writing: 19.05.2023

Scope of Note: Review of the cable ampacity rating for the proposed 110kV underground cable route of the grid connection for the planned Carrownagowan Wind Farm

Documents & Data Issued for Review: N/A

Background

TLI Group (the Consultant) were engaged by Malachy Walsh & Partners (the Client) to prepare technical documentation for the planning application of the grid connection for the planned Carrownagowan Wind Farm. This grid connection will be approximately 25km long and consist entirely of underground cabling, which will be a 1600mm² Al XLPE single-core cable per phase. The grid connection offer from EirGrid states that the cable is to be 110kV 1600 XLPE cable (with rating equivalent Summer/Winter rating of 178/209 MVA)

As part of the detailed design we will need to prove that the cable can achieve 178/209 MVA (when operating at 110kV). Are there any pinch points on the cable route that may need to be assessed further now in advance of the planning amendment being submitted. A cable ampacity study was carried out for the proposed 110kV underground cable route between Ardnacrusha 110kV Substation and the planned Carrownagowan Wind Farm substation, considering the currently known information and anticipated trench designs to be used. The purpose of this Technical Note is to outline the results obtained, with the objective of demonstrating that the maximum cable rating of the cables typically used is not expected to be exceeded during their operation.

The purpose of this Technical Note is to outline the calculations completed to ensure that the cables selected for the project will have sufficient capacity to carry the MEC for the project. The cable ratings which have been completed as part of this study include:

	Trench Type	Description	Notes
01	Standard Trench Design, Three ducts in trefoil configuration	160mm HDPE ducts, 950mm depth to top of duct, no separation between ducts	<i>Assessment of Standard Trench, Single Duct Scenario</i>
02	Horizontal Directional Drilling (HDD), single borehole carrying three ducts in trefoil configuration	180mm HDPE ducts, 5,000mm depth to top of duct, no separation between ducts	<i>Max anticipated depth for HDD under-crossing</i>
03	Horizontal Directional Drilling (HDD), triple borehole carrying one phase per duct in flat formation.	180mm HDPE ducts, 5,000mm depth to top of duct, 1,000mm separation centre to centre for selected ducts	<i>Max anticipated depth for HDD under-crossing</i>

Table 1 – Trench Type Summary

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Details

Below are the key parameters considered for this study.

Cable Study Parameters			
<i>Cable Size:</i>	<i>1600mm.sq Al Cable</i>		
<i>Nominal Voltage:</i>	<i>110kV</i>		
<i>Power:</i>	<i>178MW Summer / 209MW Winter</i>		
<i>Power Factor:</i>	<i>0.95 (Type C Connection)</i>		
<i>Cable Route Length:</i>	<i>Approx. 25km</i>		
<i>Permissible conductor temperature:</i>	<i>90°C</i>		
<i>Cable Screen Bonding:</i>	<i>Cross Bonding</i>	<i>Single Point Bonded</i>	
<i>Cable Trench Design:</i>	<i>See Appendices B-D</i>		
<i>Seasonal Characteristics</i>	<i>Summer</i>	<i>Spring/Autumn</i>	<i>Winter</i>
<i>Ambient Temp (Soil)</i>	<i>20°C</i>	<i>15°C</i>	<i>10°C</i>
<i>Soil Thermal Resistivity</i>	<i>1.2 K·m/W</i>	<i>1.0 K·m/W</i>	<i>1.0 K·m/W</i>
<i>Backfill Thermal Resistivity</i>	<i>1.0 K·m/W</i>	<i>1.0 K·m/W</i>	<i>0.85 K·m/W</i>

Table 2 - Cable Study General Parameters

To be noted that only summer characteristics were considered as part of this ampacity study, as those represent the worst-case scenario for seasonal characteristics.

The cable ampacity ratings were calculated in accordance with the current edition of IEC 60287 for steady-state operation of cables, using the software Cableizer for modelling the several anticipated system configurations for this project. The cable systems were modelled to a maximum conductor temperature of 90°C.

Deviations to the results may be expected where the actual construction characteristics differ.

$$I_c = \frac{MVA}{\sqrt{3} * Vl}$$

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Cable Study Results

Appendix A presents a summary of the Cable Rating Results detailed below.

➤ 110kV Standard Trench Design, Single Duct (Depth 1315mm)

A cable rating study was completed for a **SolidAL 1600mm² AL XLPE (110kV) UGC** operating at 110kV, using the standard single circuit 110kV trench design detailed in **Appendix B**, wherein the depth to top of duct is of 950mm and the backfill surrounding the duct is CBGM. Cable rating calculations were carried out under summer and winter conditions.

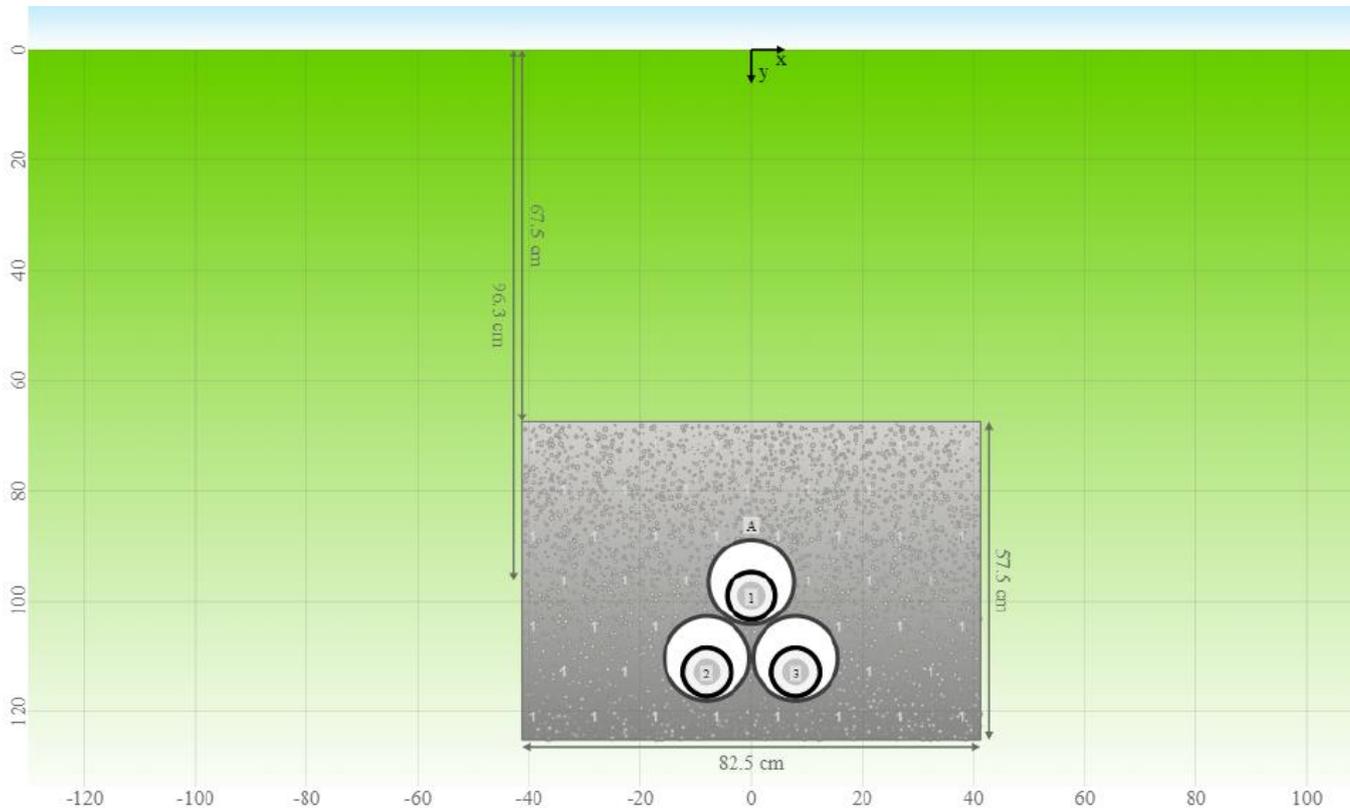
Using this arrangement, the circuit is capable of carrying a maximum full load current of **1039A** without exceeding the cables max insulative property of 90°C. Therefore, 1600mm² Al XLPE (110kV) UGC when installed using the standard trefoil trench design is capable of achieving the required maximum full load (178MW) under summer operating conditions. This will represent a maximum cable loading percentage of **90%** against the stated grid offer from the Transmission System Operator (TSO).

In Winter operating conditions with this standard trench arrangement will have a maximum full load current of **1177.7A** without exceeding the cables max insulative property of 90°C. Therefore, 1600mm² Al XLPE (110kV) UGC is capable of achieving the required maximum full load (219MW) under winter operating conditions. This will represent a maximum cable loading percentage of **98%** against the stated grid offer from the Transmission System Operator (TSO).

The results obtained are included below for reference in Table 3 below.

05-641 Carrownagowan WF 110kV UGC													
Cable Rating Study Results													
1600mm ² Al XLPE Cable													
Rev0 [19.05.23]													
Cable Rating Study Results													
Rating Sheet Ref	Season	Ambient Temp (°C)	Backfill Res. (K.m/W)	Soil Res. (K.m/W)	Duct Config.	Circuits Spacing (mm)	Bonding Arrangement	Duct Depth (mm)	Required Amps (A)	Max Ampere Rating @ 90°C	MW Loading	Loading Capacity	Rating met
SolidAl 1600 Al_Trefoil_Summer_SPB	Summer	20	1	1.2	Trefoil 160mm HDPE	N/A	Single Point Bonded	950	934	1039.0	188.1	90%	Yes
SolidAl 1600 Al_Trefoil_Winter_SPB	Winter	10	0.85	1	Trefoil 160mm HDPE	N/A	Single Point Bonded	950	1097	1177.7	213.2	93%	Yes

Table 3 - Standard Trench Results



Systems

Following systems are active in the arrangement:

System	Object	Current [A] I_c	Temp. [°C] θ_c θ_e (θ_{de})	Losses [W/m] W_{sys} μW_{sys}
System A	SolidAl 1600mm ² Al XLPE (110kV) C111321	1039.0	90.0 79.5 (68.6)	96.5

Figure 1 – Standard Trench Results Extract – Summer conditions

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➤ 110kV Horizontal Directional Drill, Single Shot Trefoil Formation (Depth 5000mm)

Pinch points identified along the proposed UGC route with the requirement of Horizontal Directional Drill (HDD) to cross obstacles, warranted further assessment. An HDD crossing cable rating study was completed for a **SolidAl 1600mm² AL XLPE (110kV) UGC**, using a single shot HDD with a 600mm core with 180mm HDPE ducts in a trefoil formation within this drill core, with bentonite surround. A maximum HDD depth of 5000mm has been assumed for this study; shallower depths will be more favourable.

Cable rating calculations were carried out under summer and winter conditions for these HDD simulations. Using **SolidAl 1600mm² AL XLPE (110kV) UGC**, set to operate at the maximum temperature without exceeding the insulative property of the existing cable at 90°C showed that the current carrying capacity is **912.7A¹** which results with this install arrangement under achieving. In summer conditions, this installation will not achieve the required **178MW** summer rating /grid offer from the Transmission System Operator (TSO).

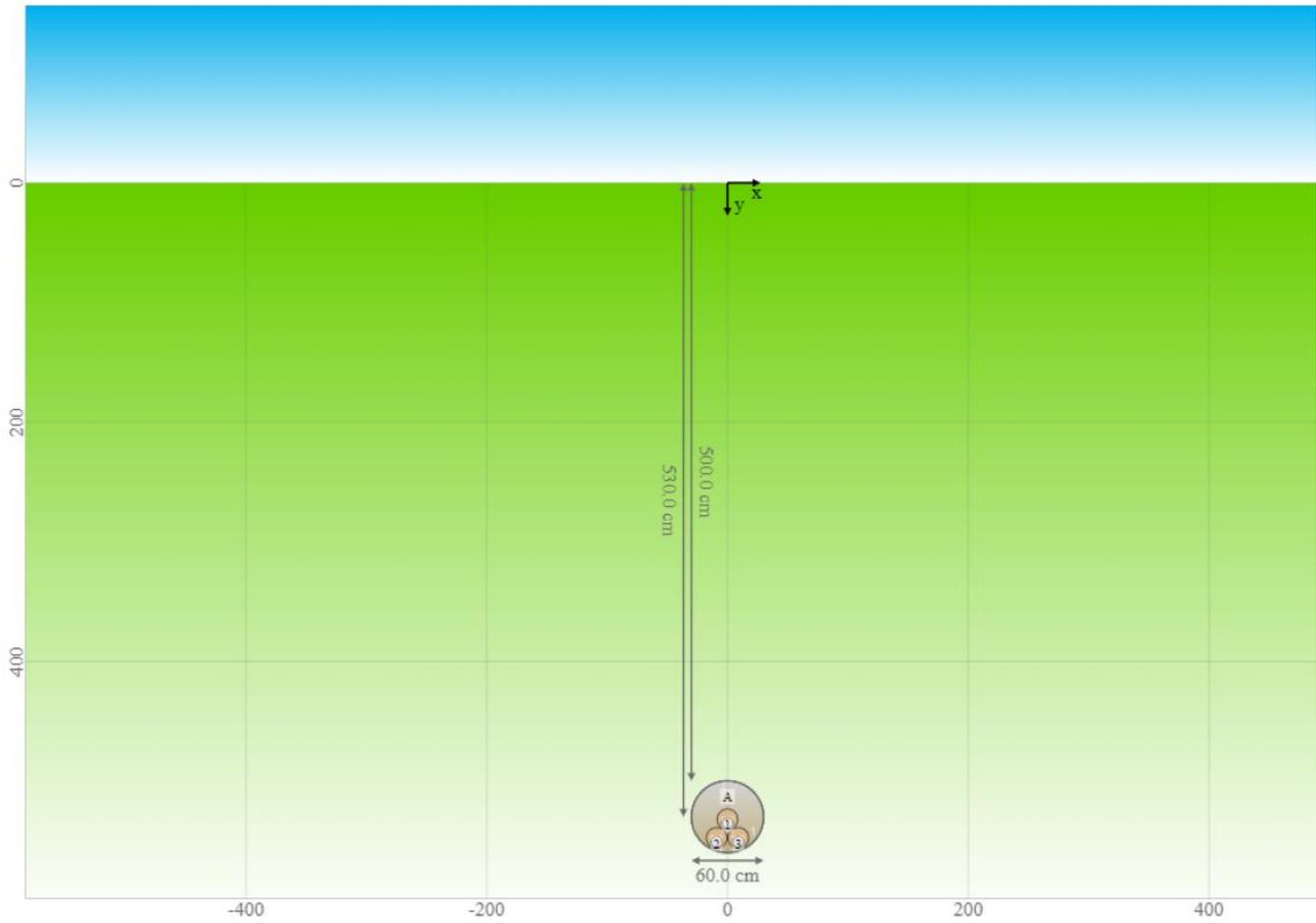
In winter conditions, this HDD installation will not achieve the required **209MW** winter rating /grid offer from the Transmission System Operator (TSO). The current carrying capacity of the selected cable is **1053.3A**, resulting in this arrangement also under achieving the minimum rating requirement.

The results obtained are included in Table 4 below,

05-641 Carrownagowan WF 110kV UGC													
Cable Rating Study Results													
1600mm ² Al XLPE Cable													
Rev0 [19.05.23]													
Cable Rating Study Results													
Rating Sheet Ref	Season	Ambient Temp (°C)	Backfill Res. (K.m/W)	Soil Res. (K.m/W)	Duct Config.	Circuits Spacing (mm)	Bonding Arrangement	Duct Depth (mm)	Required Amps (A)	Max Ampere Rating @ 90°C	MW Loading	Loading Capacity	Rating met
SolidAl 1600 Al_180D Single 600mm Core_Summer [5000 Depth]_CB	Summer	20	1	1.2	Individual 180mm HDPE	600	Cross Bonded	5000	934	912.7	165.2	102%	No
SolidAl 1600 Al_180D Single 600mm Core_Winter [5000 Depth]_CB	Winter	10	0.85	1	Individual 180mm HDPE	600	Cross Bonded	5000	1097	1053.3	190.6	104%	No

Table 4 - HDD Crossing Single Drill Core Results (5000mm Depth)

¹ Rated Current formula =
$$I_c = \frac{MVA}{\sqrt{3} * V_l}$$



Systems

Following systems are active in the arrangement:

System	Object	Current [A] I_c	Temp. [°C] $\theta_c \theta_e (\theta_{de})$	Losses [W/m] $W_{sys} \mu W_{sys}$
System A	SolidAl 1600mm ² Al XLPE (110kV) C111321	912.7	90.0 81.9 (79.0)	73.5

Figure 2 –Single Shot HDD Trefoil Formation Results Extract – Summer conditions

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➤ 110kV Horizontal Directional Drill, Triple Shot Flat Formation (Depth 5000mm)

Given that the HDD with a single drill core with the ducting enclosed in a trefoil formation did not achieve required specifications, it is proposed that the HDD will utilize three separate drill shots to accommodate the circuit in individual phases, with the ducts spaced by 1000mm (centre to centre). An HDD crossing cable rating study was completed for a **SolidAL 1600mm² AL XLPE (110kV) UGC**, implementing three individual HDD shots within 355mm cores with 180mm HDPE duct install per drill core, within bentonite surround.

A maximum HDD depth of 5000mm has been assumed for this study; shallower depths will be more favourable. Cable rating calculations were carried out under summer and winter conditions for these HDD simulations. Using **SolidAL 1600mm² AL XLPE (110kV) UGC** in summer conditions, with simulations set to operate at the maximum temperature without exceeding the insulative property of the existing cable of 90°C showed that the current carrying capacity of the cable is **1035.9A**, achieving the required maximum full load (178MW). This will represent a maximum cable loading percentage of **90%** against the stated grid offer from the Transmission System Operator (TSO).

In Winter operating conditions with this HDD arrangement will have a maximum full load current of **1194.4A** without exceeding the cables max insulative property of 90°C. Therefore, 1600mm² Al XLPE (110kV) UGC is capable of achieving the required maximum full load (209MW) under winter operating conditions. This will represent a maximum cable loading percentage of **92%** against the stated grid offer from the Transmission System Operator (TSO).

The results obtained are included in **Table 5: HDD Crossing Triple Shot Flat Results (5000mm Depth)** below.

HDD Cable Rating Study Results (Triple Shot Flat)													tli GROUP	
1600mm ² Al XLPE Cable														
Rev0 [19.05.23]														
Cable Rating Study Results														
Rating Sheet Ref	Season	Ambient Temp (°C)	Backfill Res.	Soil Res. (K.m/W)	Duct Config.	Drill Core Sizing	Bonding Arrangement	Duct Depth (mm)	Required Amps (A)	Max Ampere	MW Loading	Loading Capacity	Rating met	
SolidAl 1600 Al_180D Triple 355mm Core Shots_Summer [5000 Depth]_CB	Summer	20	1	1.2	Individual 180mm HDPE 1000mm Center to Centre	355	Single Point Bonded	5000	934	1035.9	187.5	90%	Yes	
SolidAl 1600 Al_180D Triple 355mm Core Shots_Winter [5000 Depth]_CB	Winter	10	0.85	1	Individual 180mm HDPE 1000mm Center to Centre	355	Single Point Bonded	5000	1097	1194.4	215.1	92%	Yes	

Table 5: HDD Crossing Triple Shot Flat Results (5000mm Depth)

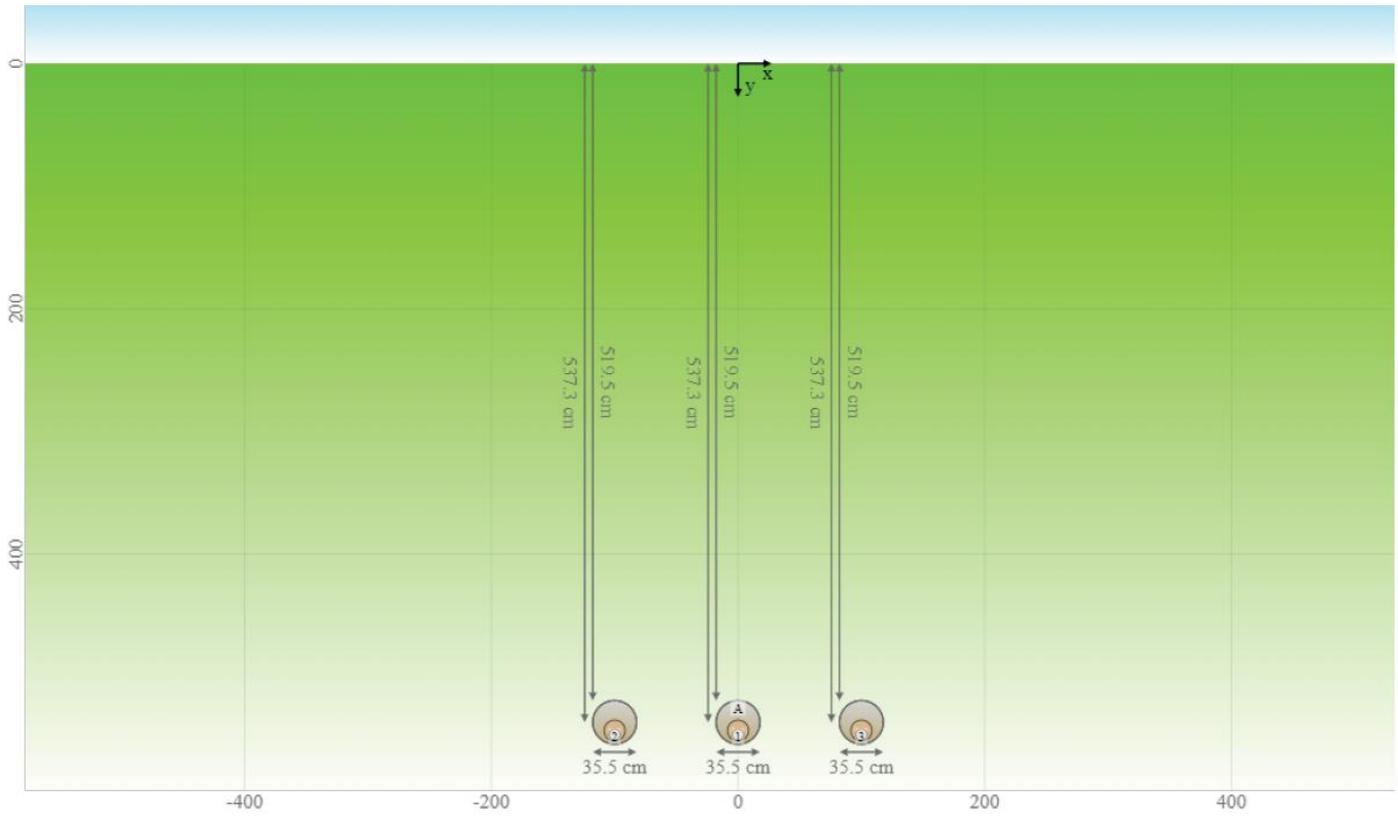
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Systems

Following systems are active in the arrangement:

System	Object	Current [A] I_c	Temp. [°C] θ_c θ_e (θ_{de})	Losses [W/m] W_{sys} μW_{sys}
System A	SolidAl 1600mm ² Al XLPE (110kV) C111321	1035.9	90.0 79.9 (76.4)	87.6

Figure 3: Triple Shot HDD Flat Formation Results Extract – Summer conditions

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➤ *Cable Rating Study Results Summary*

The Cable Rating Study Checks completed have indicated that it should be possible to carry the maximum export capacity of the cable at **178MW** on a standard 110kV single circuit **1600mm² Al XLPE cable** for the majority of the grid connection without exceeding the proposed recommended maximum conductor temperature of 90°C when using the proposed trench designs with a variation of HDD arrangements to achieve the stated grid offer from the Transmission System Operator (TSO).

It can be seen from **Appendix A** that the proposed **1600mm² AL XLPE cable** will have a **maximum power capacity of 188MW when installed in the standard trench design** under summer conditions. There is a reduction in the load capacity of the cable system if installed at a depth of 5000mm for an **HDD crossing in trefoil formation**, where it **would have a maximum capacity of 165.2MW**. As such, it is proposed that the HDD will utilize three drill shots to accommodate the circuit in flat formation at a depth of 5000mm, **resulting in a maximum capacity of 187.5MW**.

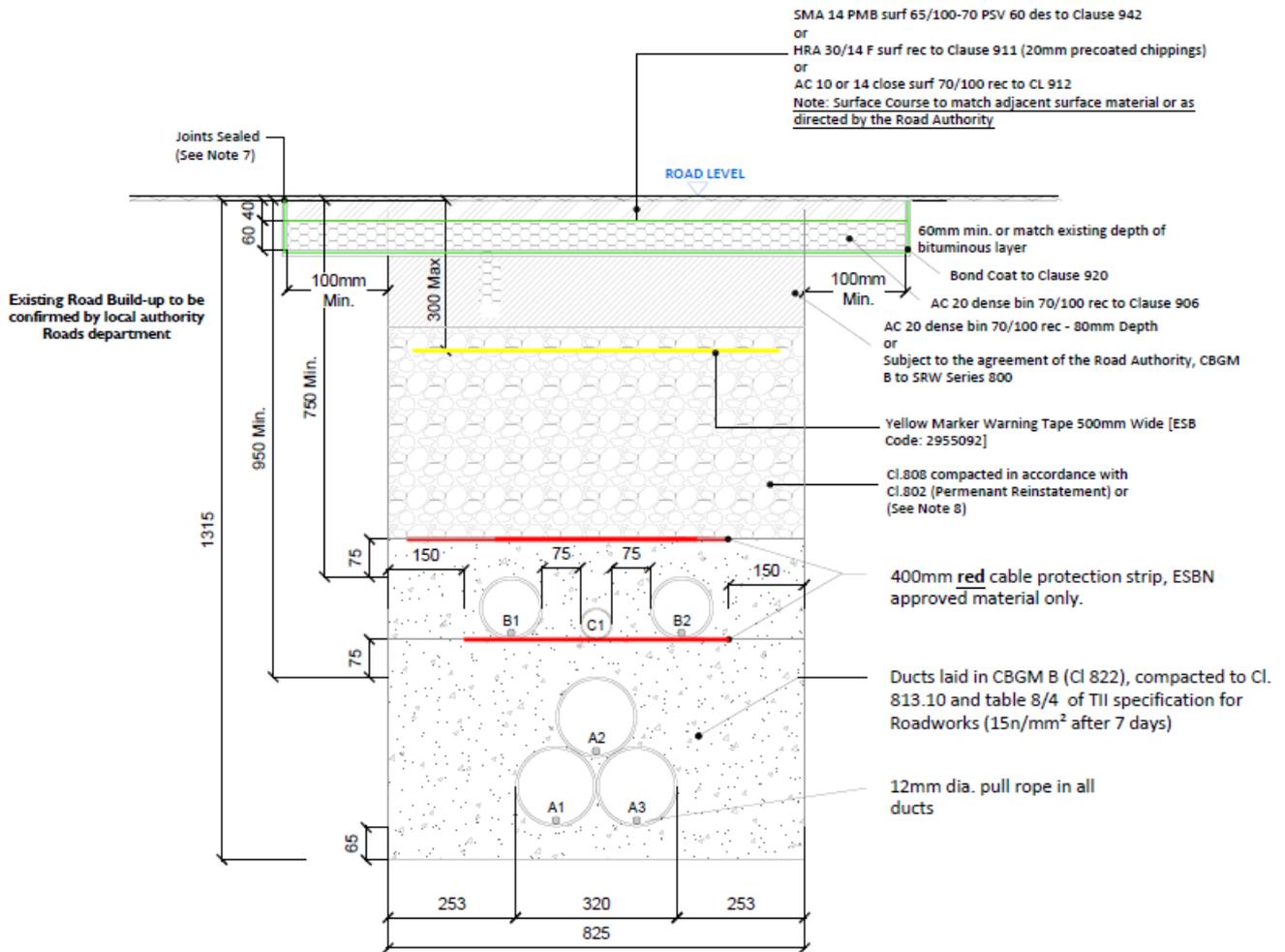
As part of the detailed design process, the number of existing service crossings will be identified on the route. The exact number of service crossings will need to be confirmed during construction as the service information provided by the utilities is indicative only. The size and depth of the services to be crossed is not known at this stage and will be confirmed during construction. The 110kV ducting will cross the existing services using either an under-crossing trench design or an over-crossing trench design as to be determined during construction. Other services may be encountered on the route during construction.

Appendix A – Cable Rating Results Summary

05-641 Carrownagowan WF 110kV UGC													
Cable Rating Study Results													
1600mm ² Al XLPE Cable													
Rev0 [19.05.23]													
Cable Rating Study Results													
Rating Sheet Ref	Season	Ambient Temp (°C)	Backfill Res. (K.m/W)	Soil Res. (K.m/W)	Duct Config.	Circuits Spacing (mm)	Bonding Arrangement	Duct Depth (mm)	Required Amps (A)	Max Ampere Rating @ 90°C	MW Loading	Loading Capacity	Rating met
SolidAl 1600 Al_Trefoil_Summer_SPB	Summer	20	1	1.2	Trefoil 160mm HDPE	N/A	Single Point Bonded	950	934	1039.0	188.1	90%	Yes
SolidAl 1600 Al_Trefoil_Winter_SPB	Winter	10	0.85	1	Trefoil 160mm HDPE	N/A	Single Point Bonded	950	1097	1177.7	213.2	93%	Yes
Rating Sheet Ref	Season	Ambient Temp (°C)	Backfill Res. (K.m/W)	Soil Res. (K.m/W)	Duct Config.	Drill Core Sizing (mm)	Bonding Arrangement	Duct Depth (mm)	Required Amps (A)	Max Ampere Rating @ 90°C on System A	MW Loading	Loading Capacity	Rating met
SolidAl 1600 Al_180D Single 600mm Core_Summer [5000 Depth]_CB	Summer	20	1	1.2	Individual 180mm HDPE	600	Cross Bonded	5000	934	912.7	165.2	102%	No
SolidAl 1600 Al_180D Single 600mm Core_Winter [5000 Depth]_CB	Winter	10	0.85	1	Individual 180mm HDPE	600	Cross Bonded	5000	1097	1053.3	190.6	104%	No
Rating Sheet Ref	Season	Ambient Temp (°C)	Backfill Res. (K.m/W)	Soil Res. (K.m/W)	Duct Config.	Drill Core Sizing (mm)	Bonding Arrangement	Duct Depth (mm)	Required Amps (A)	Max Ampere Rating @ 90°C	MW Loading	Loading Capacity	Rating met
SolidAl 1600 Al_180D Triple 355mm Core Shots_Summer [5000 Depth]_CB	Summer	20	1	1.2	Individual 180mm HDPE 1000mm Center to Centre	355	Single Point Bonded	5000	934	1035.9	187.5	90%	Yes
SolidAl 1600 Al_180D Triple 355mm Core Shots_Winter [5000 Depth]_CB	Winter	10	0.85	1	Individual 180mm HDPE 1000mm Center to Centre	355	Single Point Bonded	5000	1097	1194.4	215.1	92%	Yes



Appendix B – Standard 110kV Trench Design – Section through Public Road



A = 160mm: Outer Diameter HDPE ESB Approved Duct, SDR=21 (Power) [ESB Code: 9317552]

B = 125mm: Outer Diameter HDPE ESB Approved Duct, SDR=17.6 (Comms) [ESB Code: 9317552]

C = 63mm: ECC Earth Continuity Conductor [ESB Code: 9317552]