Memo to:		**Memo No:**	10298284-AM 22-2958 Rev.4
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		Date:	2022-19-10
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Magnetic field contour calculation for 110 kV cable connection ESDV – ESDH

TenneT has redesigned the trace for the 110 kV cable connection ESDV-ESDH. For this purpose, TenneT would like to know the magnetic field contour at a distance of 1 m above the ground level (maaiveld) for the whole trace in order to ensure that the magnetic field limits fall within the advised limits of RIVM. In case that is not possible, TenneT would like to take mitigation actions to make sure that the limitations are observed.

1 FUNCTIONAL SPECIFICATIONS

The following functional requirements have been set by TenneT for the cable system [1]:

- Cable system name — ESDV – ESDH
- Phase voltage — 110 kV
- Maximum voltage — 123 kV
- Nominal frequency — 50 Hz
- Transport capacity — 150 MVA
- Current — 788 A
- 1-phase short-circuit current (earth current) — 25 kA
- Duration of the 1-phase short-circuit current — 1 s
- 3-phase short-circuit current — 40 kA
- Duration of the 3-phase short-circuit current — 1 s
- Maximum conductor temperature — 90 °C

The magnetic field calculations are made for the 1000 mm^2 Aluminum cable according to the RFC08. The details for the cable are shown in the Figure 1 below.

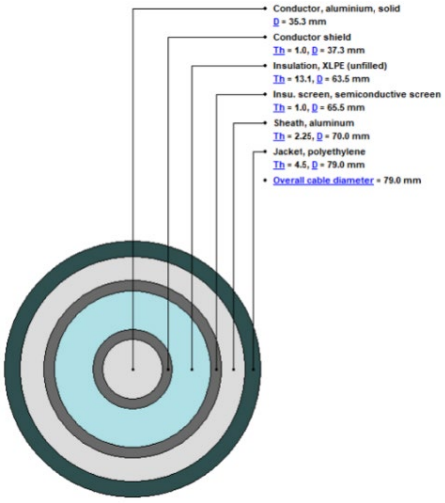

Figure 1 Cross section of the 1000 mm^2 solid Aluminium cable

Figure 2 shows the number of HDDs in the whole connection and their updated relative lengths along with the locations of the joints present.

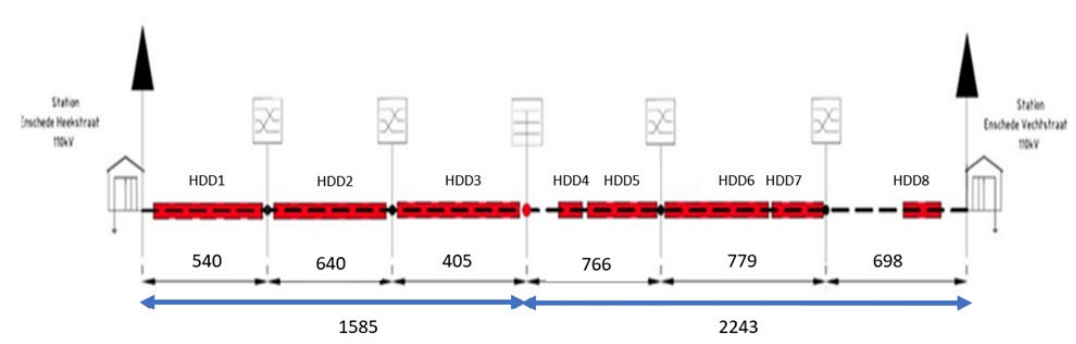

Figure 2 Length of HDDs for the whole trace

The cable configuration for the cables in the direct burial as used for the magnetic field calculation is shown in Figure 3.

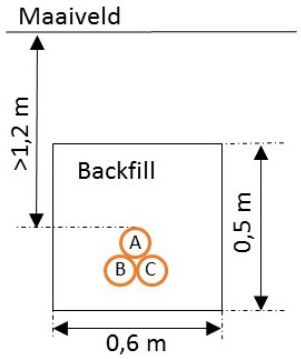

Figure 3 Configuration of direct burial [1]

The cable configuration of the horizontal directional drilling (HDD) as used for the magnetic field calculation is shown in Figure 4. The pipe dimensions are 163 mm inner diameter and 200 mm outer diameter filled with water and the pipe material is polyethylene.

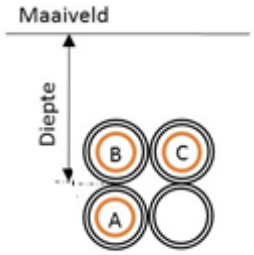

Figure 4 Configuration of horizontal directional drilling [1]

2 MAGNETIC FIELD CALCULATIONS FOR HORIZONTAL DIRECTIONAL DRILLINGS (HDDs)

2.1 Magnetic field at the entrance of an HDD

The magnetic field around the cable for the HDD is calculated using the Cymcap 8.1 rev 2 for the configuration shown in Figure 5.

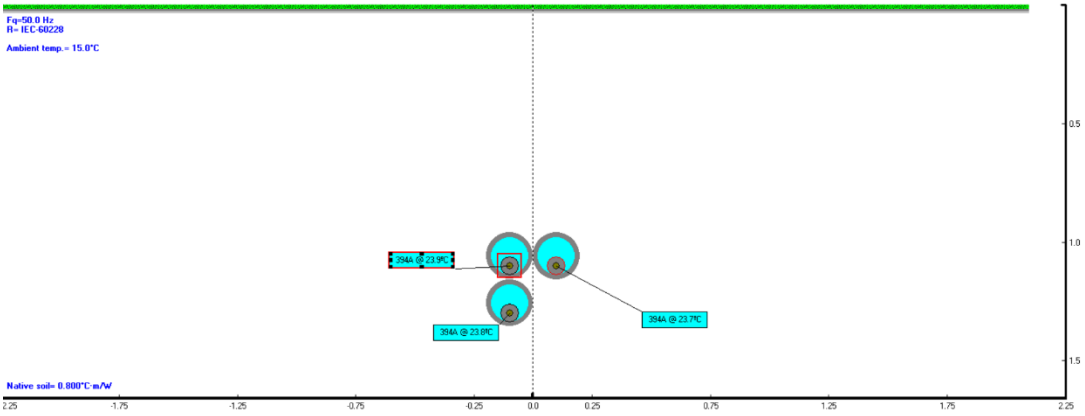

Figure 5 Configuration of HDD

In the case of an HDD, the worst case (which is the maximum magnetic field at a vertical distance of 1 m above the ground level) is experienced at the point where the HDD is closest to the ground level (maaiveld). This is at the same depth as the direct burial. This is valid for all the HDDs.

By a nominal current of 50 % (394 A), the maximum magnetic field calculated as 4.72 µT and it complies with the European limitation of 100 µT for the public.

Also, the 0.4 µT limit as defined by RIVM lies in the vicinity of the 2 x 7 m [2]. According to the RIVM document [2], the rounding off for the distances is not clearly defined. In order to avoid any potential safety and health risks, the horizontal contour for the 0.4 µT is not rounded off and kept as the original calculated value. Furthermore, due to the limitation of horizontal space in actual situation around the cable therefore the 2 x 7 m is considered as a safe contour and not rounded up to 2 x 10 m. The results for this are presented in Figure 6 below.

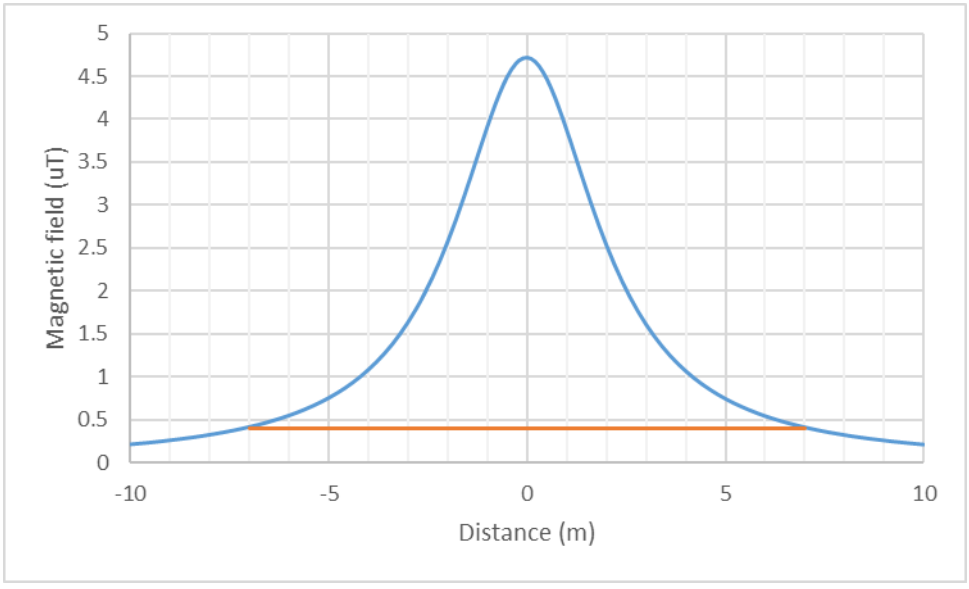

Figure 6 Contour of magnetic field at the entrance point for all HDDs

2.2 Magnetic field at the shallowest burial depth of an HDD

The shallowest HDD in the whole trace is HDD 5, located at a depth of 10.83 m below the ground level [3] . At the deepest point of this HDD, the magnetic field is calculated. The results are shown in Figure 7 below.

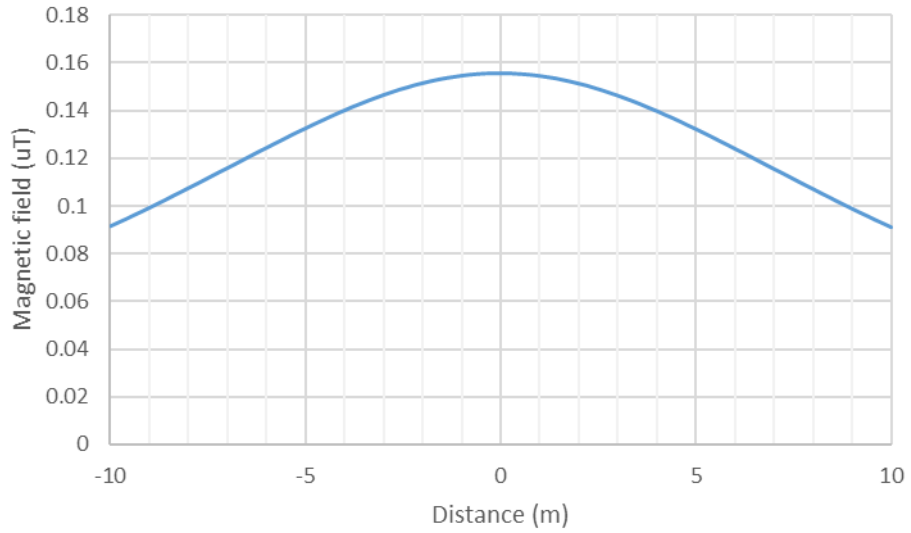

Figure 7 Contour of magnetic field at the deepest point of the HDD closest to the ground level

By a nominal current of 50 % (394 A), the maximum magnetic field calculated at 1 meter above the ground is 0.16 µT (rounded up to 2 decimal places) and it complies with the European limitation of 100 µT for the public. The 0.4 µT limit according to RIVM [2] is not applicable here since the maximum magnetic field observed is less than 0.4 µT.

2.3 Magnetic field at the location where the 0.4 µT contour disappears

For this section, the depth of the HDD is found out where the magnetic field of 0.4 µT will disappear. For this purpose, several iterations of the simulations were done using the Cymcap 8.1 rev 2 to determine the depth of HDD where the magnetic field is at a maximum of 0.4 µT at a height of 1 m above the ground level at a nominal current of 50 % (394 A). This vertical distance is found out to be 6.5 m between the ground level and the heart of the HDD. The magnetic field contour around the HDD at the depth of 6.5 m is as shown in the Figure 8 below. At a depth greater than 6.5 m, the maximum magnetic field at 1 m above ground level will be less than 0.4 µT.

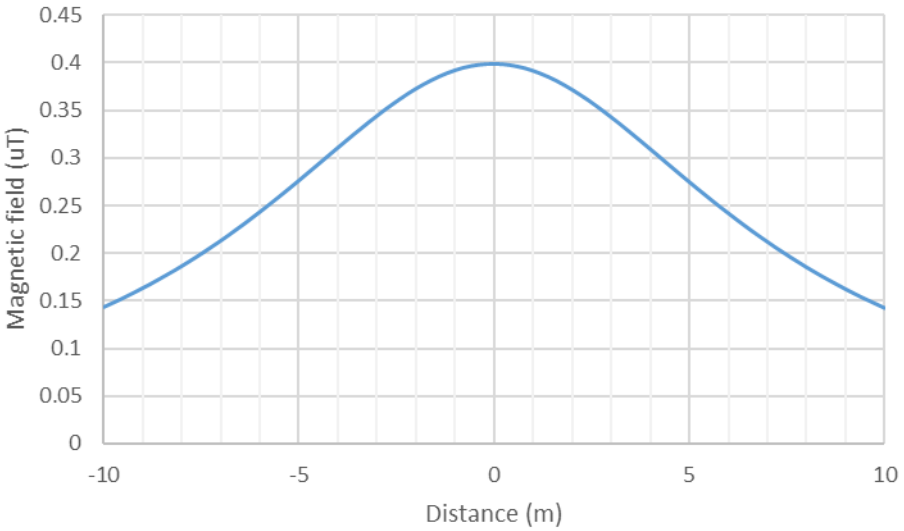

Figure 8 Magnetic field contour of HDD at a depth of 6.5 m where the maximum value is 0.4 µT

3 DIRECTLY BURIED

The magnetic field around the cable for the directly buried is calculated using the Cymcap 8.1 rev 2 for the configuration shown in Figure 9.

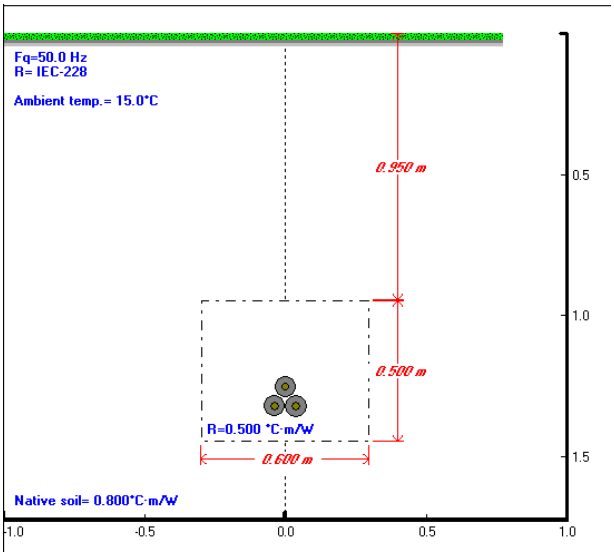

Figure 9 Configuration of the direct burial

By a nominal current of 50 % (394 A), the maximum magnetic field is 1.46 µT at a vertical distance of 1 m above the ground and it complies with the European limitation of 100 µT for the public. The 0.4 µT limit as defined by RIVM lies in the vicinity of the 2 x 4 m which is rounded up as 2 x 5 m [2]. The results for this are presented in Figure 10 below.

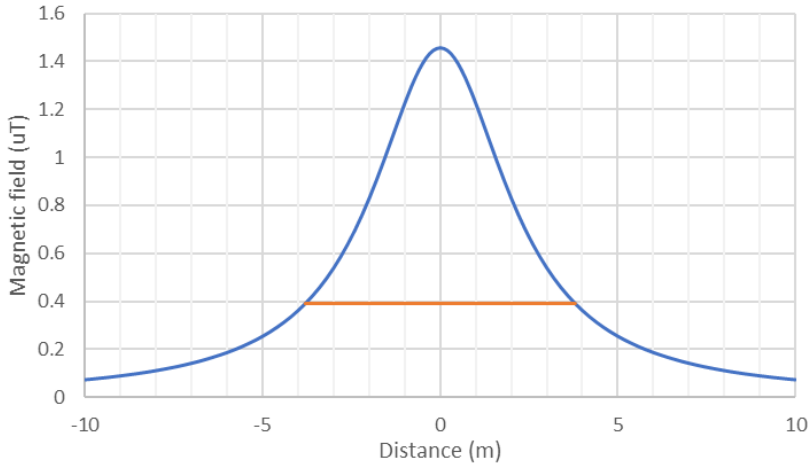

Figure 10 Contour of magnetic field for the direct burial

4 CONCLUSIONS

Using a nominal current of 50 % (394 A) for the connection ESDV-ESDH, the maximum magnetic field is calculated for all HDDs and direct burials. The results comply with the 100 µT European limit for the public. The maximum magnetic field is calculated to be 4.72 µT and 1.46 µT, respectively, for the HDDs and the direct burial at the location closest to the ground level (maaiveld). The 0.4 µT limit defined by RIVM lies in the vicinity of 2 x 7 m and 2 x 5 m, respectively, for all HDDs and the direct burials.

5 REFERENCES

[1] "110 KV KABELVERBINDING ESDV-ESDH – Systeemontwerp", DNV GL rapport 17-2911, 27 november 2017

[2] Webpage: https://www.rivm.nl/hoogspanningslijnen/magneetvelden accessed on 08-06-2022

[3] Bijlage 7.7.1 Tracé lijnstukken ESDV-ESDH 2022-09-21 checked by Sweco

[4] Aanleg XLPE ESDV-ESDH – Onderzoek naar de thermische weerstand van de ondergrond, Sweco rapportage, revisie C2 29-07-2022

6 APPENDIX

The picture below shows the excel file [3] that is used for the calculations made in this memo.

Type	ID start	ID eind	Lengte(m)	Totale afstand	Equivalent G-waarde (m.K/W) from field soil measurement- SWNL0231092 Rev. C2 29-07-2022	Depth of Burial (m-mv) from pre-study-SWNL0231092 Rev. D2 28-07-2020	Ambient [°C]
Open ontgraving	Heekstraat	HDD-1-1	68	68	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-1-1	HDD-1-2	460	528	0.73	11.07	10
Open ontgraving	HDD-1-2	mof	12	540	0.8 for the soil and 0.5 for the backfill	1.3	15
Mof	mof 1		-	540			
Open ontgraving	mof	HDD-2-1	9	549	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-2-1	HDD-2-2	621	1170	0.73	16.24	10
Open ontgraving	HDD-2-2	mof	10	1180	0.8 for the soil and 0.5 for the backfill	1.3	15
Mof	mof 2		-	1180			
Open ontgraving	mof	HDD-3-1	43	1223	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-3-1	HDD-3-2	347	1570	0.56	19.92	10
Open ontgraving	HDD-3-2	mof	15	1585	0.8 for the soil and 0.5 for the backfill	1.3	15
Mof	mof 3		-	1585			
Open ontgraving	mof	HDD-4-1	20	1605	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-4-1	HDD-4-2	169	1774	0.53	12.03	10
Open ontgraving	HDD-4-2	HDD-5-1	59	1833	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-5-1	HDD-5-2	514	2347	0.46	10.83	10
Open ontgraving	HDD-5-2	mof	4	2351	0.8 for the soil and 0.5 for the backfill	1.3	15
Mof	mof 4		-	2351			
Open ontgraving	mof	HDD6-1	8	2359	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD***	HDD-6-1	HDD-6-2	373	2732	0.72	12.43	10
Open ontgraving	HDD-6-2	HDD-7-1	81	2813	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-7-1	HDD-7-2	300	3113	0.39	12.62	10
Open ontgraving	HDD-7-2	mof	17	3130	0.8 for the soil and 0.5 for the backfill	1.3	15
Mof	mof 5		-	3130			
Open ontgraving	mof	HDD-8-1	314	3444	0.8 for the soil and 0.5 for the backfill	1.3	15
HDD	HDD-8-1	HDD-8-2	266	3710	0.41	11.93	10
Open ontgraving	HDD8-2	Vechtstraat	118	3828	0.8 for the soil and 0.5 for the backfill	1.3	15