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ENVIRONMENTAL IMPACT ASSESSMENT REPORT ON THE CONNECTION INFRASTRUCTURE OF THE BALTICA B-2 AND B-3 OFFSHORE WIND FARMS

APPENDIX 6 – THERMAL IMPACT OF HIGH VOLTAGE CABLE LINES

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List of contents

Abbreviations and definitions

APV	Applicant proposed variant
FEM	Finite element method
IEC	International Electrotechnical Commission
OWF	Offshore wind farm
RAV	Rational alternative variant

1 Introduction

Electricity transmission via high-voltage cable power lines is naturally associated with the presence of thermal impact in their immediate vicinity. The thermal effect of typical cable power lines occurs as a result of power losses in the working conductor and dielectric losses in the main insulation. The thermal flux caused by individual power losses flows to the surrounding environment when the cable temperature rises above the ambient temperature. The size of the thermal impact largely depends on the technical parameters of cable lines, the method and depth of their laying, the size of external temperature fields from other sources of heat, and the thermal parameters of the soil itself.

The thermal parameters of the soil in the near-surface layer, including its thermal resistance, largely depend on the humidity, density, and type of the fraction itself. Moisture content in normal soil, like its temperature, varies periodically throughout the year. The cyclical changes in the resistance of soil are mainly caused by the variability of atmospheric conditions, particularly the amount of precipitation, exposure to direct sunlight, and the strength and direction of the wind. In Polish conditions, typical values of the thermal resistance of very wet sand are 0.5 m×K/W, while for very dry sand or clay they area 1.2–1.5 m×K/W, and for extremely dry sand – at the level of 2.5 m×K/W.

2 Description of the object analysed

The subject of the analysis is to determine the magnitude of the thermal impact of the high voltage cable line system for the evacuation of power generated by the Baltica OWF in the Baltic Sea to the National Power System. In the analysed case, the groups of cables located in the vicinity of the cable lines in question, which are the system for evacuation of power from offshore wind farms of other entities, were also taken into account.

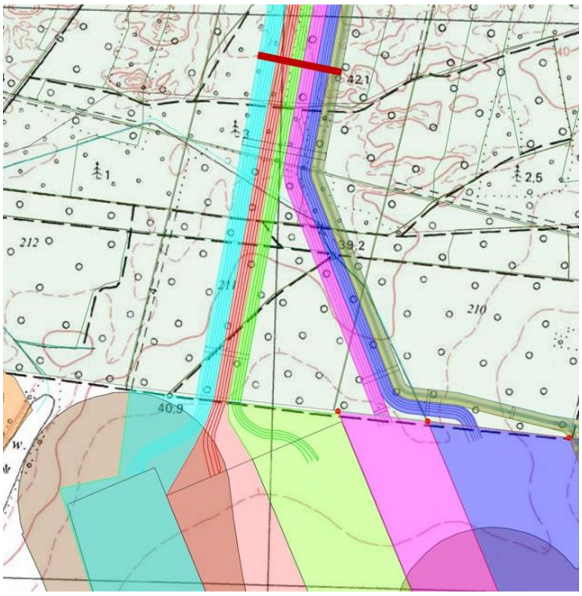

Figure 2.1. Location of the computation cross-section (red line) in which the distribution of the temperature field intensity was determined

Source: internal data

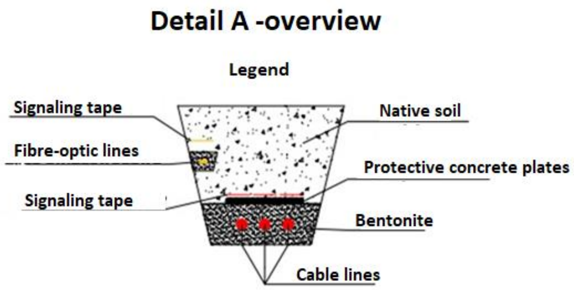

Figure 2.2. An example of a cross-section of an open trench with 3 single-phase cables with copper or aluminium conductors, constituting a single cable line

Source: internal data

The calculations were made in two variants, in accordance with the table [Table 2.1].

Table 2.1. The technical data of simultaneously operating power supply systems powering the end-user stations: Baltica 2, Baltica 3, Baltica 1, Baltex, Baltic Power, and Ocean Winds adopted for modelling the distribution of the cumulative temperature field in the cross-section shown in the figure above [Figure 2.2]

Model	**Variant (Baltica)**	**Number of lines**						**Total number**	
		Baltica 2	**Baltica 3**	**Baltica 1**	**Baltex**[1]	**Baltic Power**	**Ocean Winds**	**power lines**	**cables**
M1	APV	5	4	4	4	4	2	23	69
M2	RAV	6	5	4	4	4	2	25	75

Source: internal data

[1] *Baltex is a historic name. Currently, the procedure of assigning the PSzW to participating entities is underway. It is possible that another company will get the permit. This name has been used in this document to clearly distinguish the infrastructure. However, this should be treated as a reserve for the future entity that will acquire the PSzW permit and the technical conditions for connection to the PSE substation.*

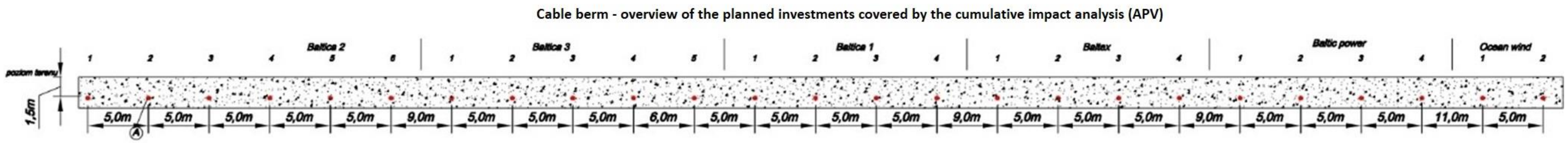

Figure 2.3. *The arrangement of individual cable lines in the cable berm as adopted for the modelling of the cumulative temperature field distribution – APV – 23 cable lines*

Source: internal data

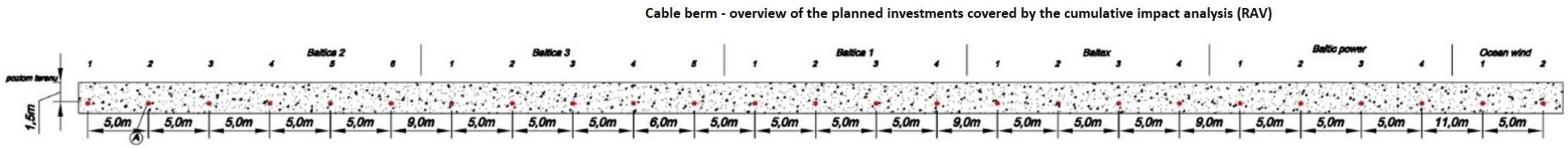

Figure 2.4. *The arrangement of individual cable lines in the cable berm as adopted for the modelling of the cumulative temperature field distribution – RAV – 25 cable lines*

Source: internal data

3 Assumptions and calculation methodology

To determine the magnitude of the cumulative thermal impact from high-voltage cable lines for the system in question, a calculation methodology based on the finite element method (FEM) has been applied.

The following thermal conductivity equation was applied for all domains:

$$\nabla (-k\nabla\theta) = Q$$

$$q = -k\nabla\theta$$

where:

∇ – the cable operator

k – thermal conductivity

$\nabla\theta$ – temperature gradient

Q – heat source

q – local flux density

The presented calculation variants are representative calculation cases and are designed to determine the expected boundary values of the temperature field around the planned power cable lines in an envelope system.

The power loads of individual cable lines have been selected to obtain the limit temperature permissible for a long time for the working conductor of an individual cable, i.e. 90°C.

The calculations were made assuming that the local native soil is homogeneous and taking into account the concrete block envelope in the immediate vicinity of the cable lines.

The calculations were made with the use of power cables commonly used in the domestic power industry with a standard construction in XLPE insulation, which enables the cable line to operate continuously at the temperature of the working core of 90°C.

The basic calculation assumptions were as follows:

- the cable laying method: flat;
- axial distances between individual cable tracks: 5 m;
- interphase axial distance in each track: 0.3 m;
- the cable laying depth: -1.5 m (-2 m for the Baltic Power OWF);
- the temperature on the soil surface: 20°C – boundary condition;
- the average value of soil resistance: 1 m×K/W;
- cables arranged in a concrete block envelope;
- the degree of cable lines load: LF = 1;
- symmetrical load on all tracks;
- frequency: 50 Hz.

The calculation assumptions for the soil conditions are compliant with the IEC 60287-3-1 standard for the territory of Poland.

Material parameters were determined based on the IEC 60287-2-1 standard.

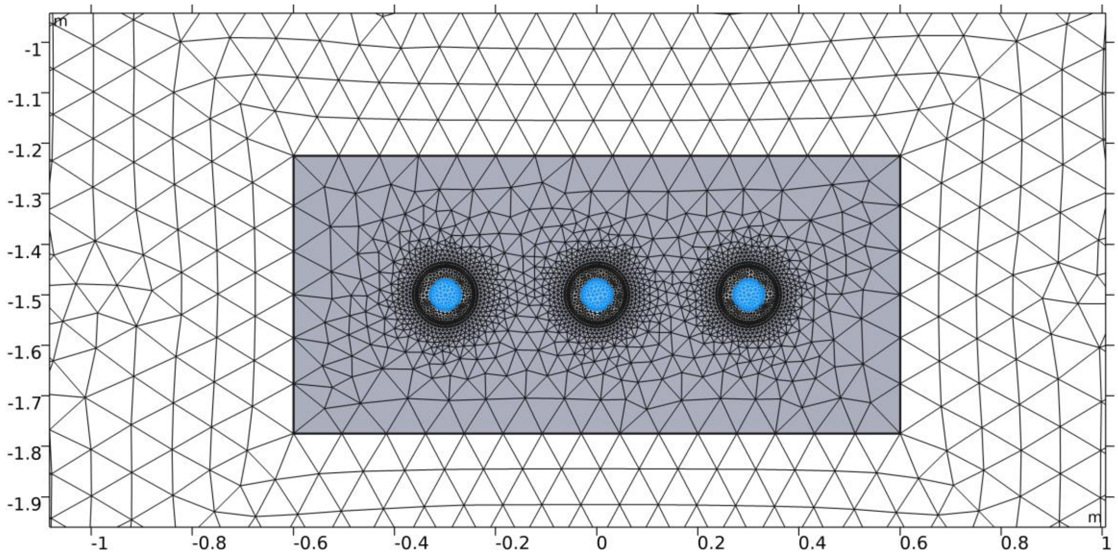

Figure 3.1. The view of the model with a calculation grid

4 Computation results

Presented below are the results of computational simulations and graphs of the temperature field distribution as a function of the vertical distance over the considered system aimed to estimate the size and extent of the significant thermal impact.

4.1 Variant proposed by the Applicant

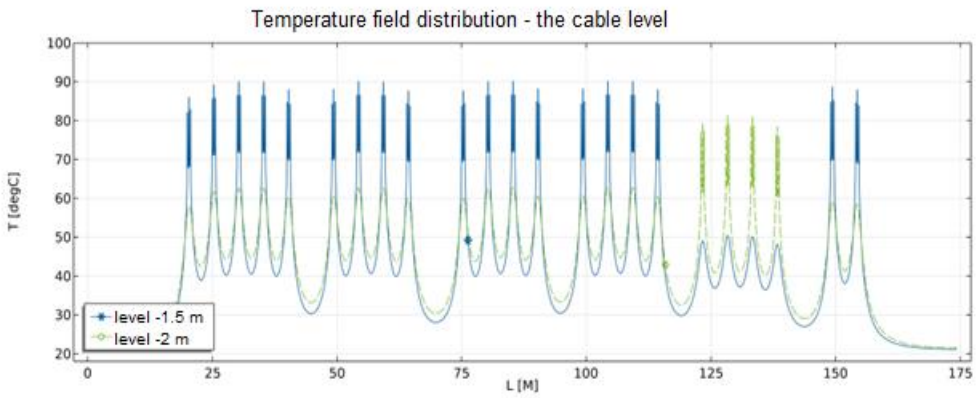

Figure 4.1. Temperature field distribution in the APV (cumulative variant)

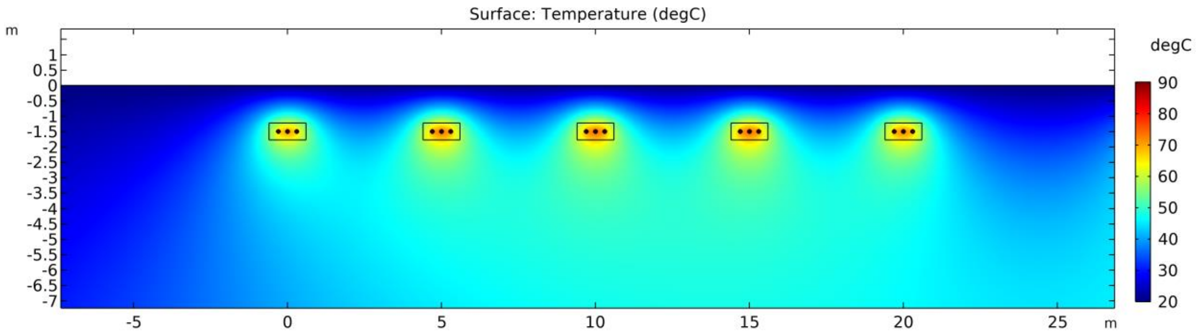

Figure 4.2. Temperature field distribution in the APV of the Baltica 2 OWF

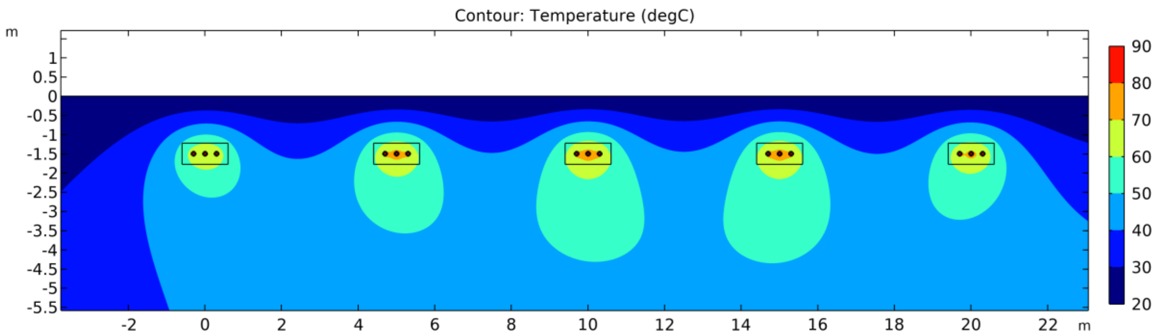

Figure 4.3. Temperature field distribution in the APV of the Baltica 2 OWF – the selected values of the limit isothermal lines

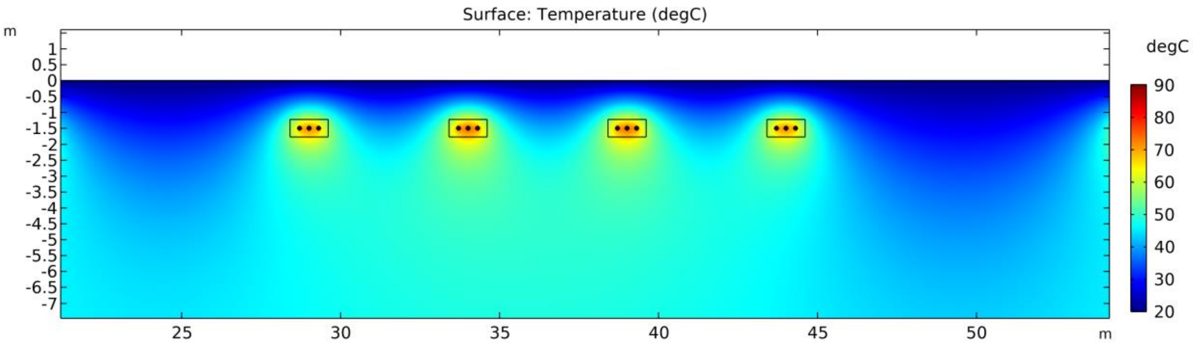

Figure 4.4. Temperature field distribution in the APV of the Baltica 3 OWF

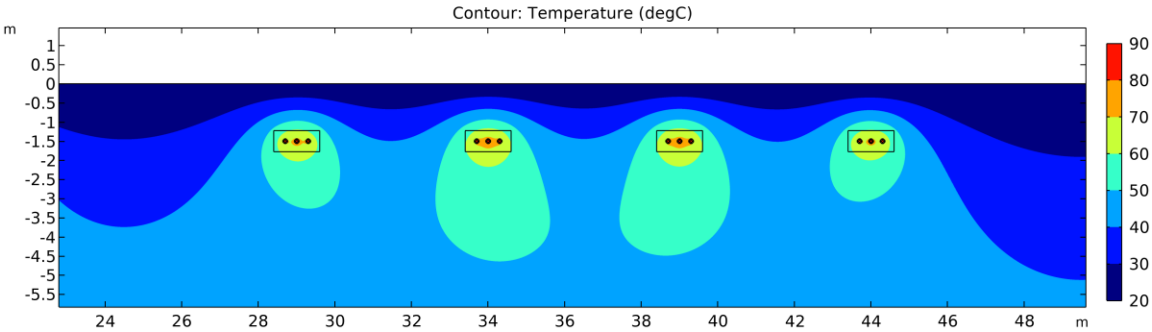

Figure 4.5. Temperature field distribution in the APV of the Baltica 3 OWF – the selected values of the limit isothermal lines

4.2 Rational alternative variant

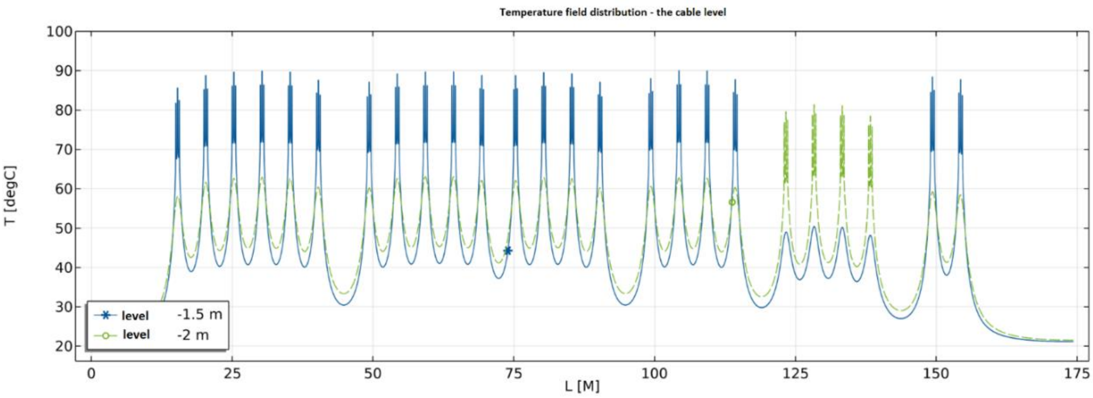

Figure 4.6. Temperature field distribution in the RAV (cumulative variant)

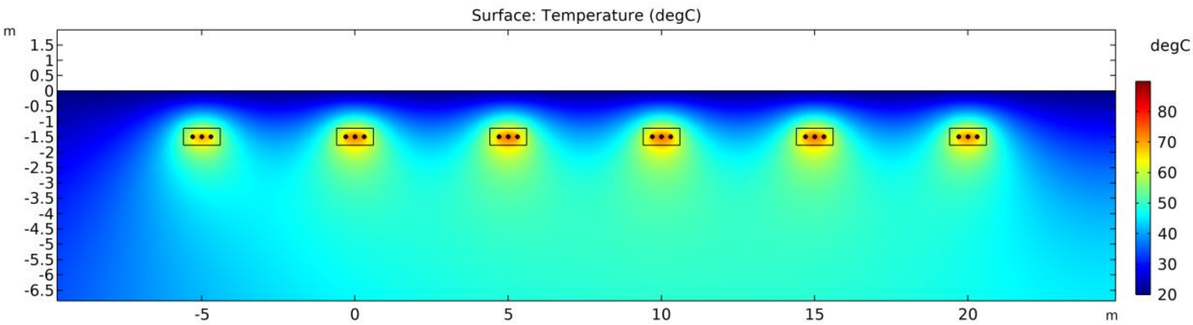

Figure 4.7. Temperature field distribution in the RAV of the Baltica 2 OWF

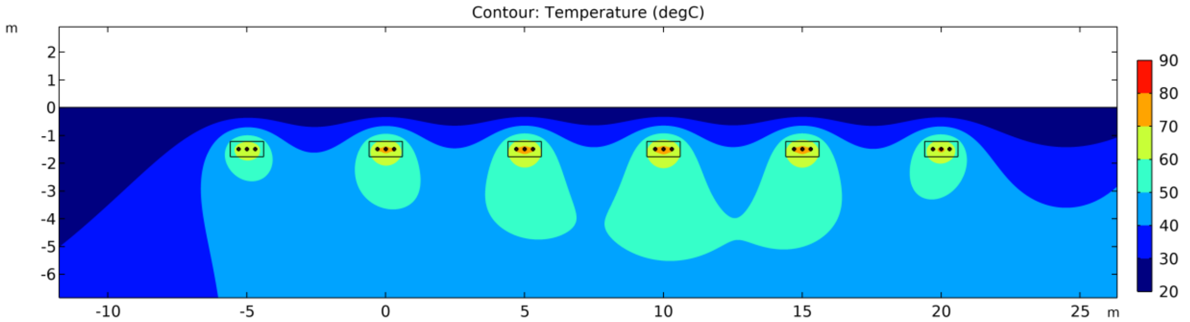

Figure 4.8. *Temperature field distribution in the RAVB of the Baltica 2 OWF – the selected values of the limit isothermal lines*

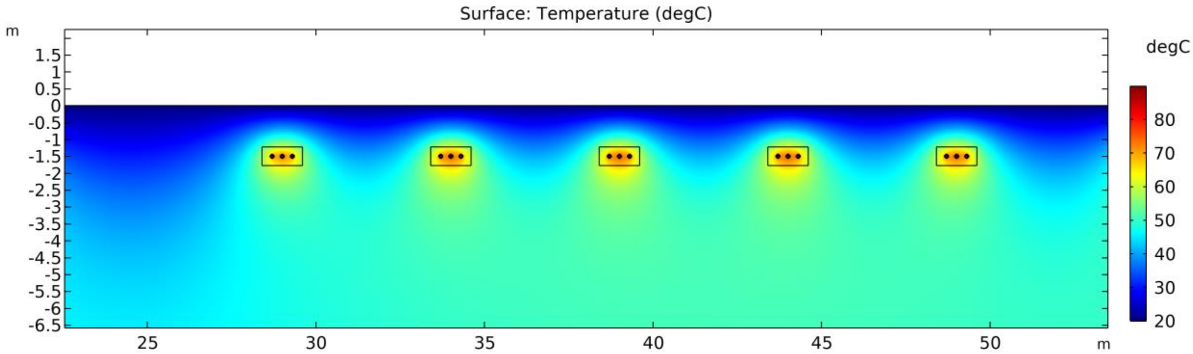

Figure 4.9. *Temperature field distribution in the RAV of the Baltica 3 OWF*

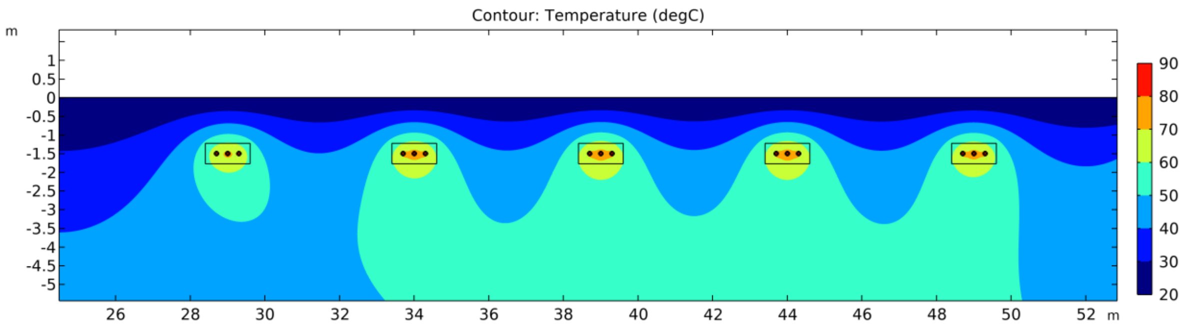

Figure 4.10. *Temperature field distribution in the RAV of the Baltica 3 OWF – the selected values of the limit isothermal lines*

5 Summary and conclusions

The obtained results indicate the occurrence of thermal influence to a limited extent. The limit isothermal lines at the level of 50°C and 60°C occur in the area immediately adjacent to the cable lines.

In extremely unfavourable hydrogeological conditions of the soil, the temperature field generated in the ground may cause drying of the soil only in the immediate vicinity of the cable system and, consequently, result in the phenomenon of local moisture migration in the direction of thermal flux from the cable system.

The method of laying individual cable lines, and in particular, the distances between the individual tracks of the power lines, enable the efficient discharge of the generated heat to the environment.

Cable lines in the extreme tracks show the lowest temperature values, which significantly affects the minimisation of the horizontal impact range on the adjacent areas. The greatest cumulative thermal impact occurs in the internal tracks, and their central cables have the highest temperature values. The cumulative impact of the entire cable berm does not significantly increase the impact of individual investors, thus there will be no significant negative impact on the environment. In accordance with IEC standards, the long-term load capacity of cables is determined by the value of the current, under the impact of which the working conductor of the cable heats up to the maximum allowable long-term operating temperature, depending on the insulation material. For the considered cables with XLPE insulation, the maximum long-term operating temperature is 90°C. At this temperature, a cable can be operated continuously throughout its design life (typically, 30 years). Exceeding the considered temperature level causes accelerated ageing of the insulation and, if it is long-lasting, significantly reduces its service life. In extreme cases (e.g. during short circuits), if the temperature of the power conductor rises significantly above the allowable long-term temperature, the insulation may deteriorate immediately.

Therefore, in normal operation conditions, all lines will operate below the analysed limit temperature, and in some cases, the cable temperature may be close to this limit (in this case 90°C), but will not exceed it under the normal operation condition. Exceedance of this temperature level is related to short-term overloads or short-circuits which, because they are automatically eliminated by the protection systems in a very short time (on the order of milliseconds or minutes), are not taken into account in the analyses – especially the analyses of the environmental impact of cables.

Since cable lines are linear objects passing through environments with different characteristics on their routes, it may be necessary to use different cable sections on different sections within one cable line. In each section, regardless of the cross-section used, the cable operates below the maximum allowable temperature (90°C). Additionally, the operation of the offshore wind farm at full generation is taken into account for the dimensioning of cables. It should be emphasised that due to the nature of offshore wind farms, the full generation will not take place continuously, and will depend on the current wind speed. This will result in fluctuations in the operating temperature of cable lines in the temperature ranges equal to or lower than those indicated in the calculations.

6 References

IEC 60287-2-1: 2006, Electric cables – Calculation of the current rating – Part 2-1: Thermal resistance

IEC 60287-3-1: 1999, Electric cables – Calculation of the current rating – Part 3-1: Sections on operating conditions and selection of cable type

7 List of tables

8 List of figures