Construction of

220 kV Loop in Loop out Paliastomi- into Ozurgeti Substation and

110 kV Double Circuit (D/C) Overhead Line from Ozurgeti Substation to Zoti HPP

DESIGN CRITERIA FOR TRANSMISSION LINES

00	18.08.2021	Issued for Approval	N.Celikkaya	H.O.Bulut	K.Karagoz
Rev. No.	Date	Description	Prepared by	Checked by	Approved by

Employer Logo and Business Name	Project Name
GSE — **GEORGIAN STATE ELECTROSYSTEM** 2 Baratashvili Street Tbilisi 0105 Georgia	Open Programme Extension of the Transmission Network II BMZ No. 2015 68 286
Engineer logo and business name	Contract Identification Number
FICHTNER — **Fichtner GmbH & Co. KG** Sarweystrasse 3 70191 Stuttgart / Germany	KfW/DSI/OHL-TD-Lot 2
Contractor logo and business name	Document Number
MİTAŞ ENERGY — **MITAS Energy & Metal Construction Inc.** Eski Güvercinlik Yolu No: 113 Gazi 06560 Ankara / Turkey	7145A07-EG-TWR-CLC-0200_00

Document Title	Scale	Sheet of Sheets
Design Criteria for Transmission Lines	**n.a.**	Page **1** of **4**

Table of Contents

1 INTRODUCTION

Mitas Energy and Metal Construction Inc. study of the Double Circuit 110 kV Overhead Line Ozurgeti – Zoti and Double Circuit 220 kV Overhead Line tie-in from Paliostami 1 are performed in conformance with Bidding Document PART 2 - Employer's Requirements, referred to as « Technical Specifications » in the following text, and European Standard EN 50341-1-2012 "Overhead electrical lines exceeding AC 45kV".

If no particular requirement is given explicitly by the Technical Specifications or EN 50341-1-2012 then US Standard ASCE 10-90 assuring equal or higher quality shall be applied.

The purpose of this document conditioned by the Section B2 - Particular Technical Requirements Article 2 is to ensure good comprehension and application of EN 50341-1-2012 utilized as base for the design and dimensioning of various constituent elements of Overhead Line.

As a general rule, the philosophy of the accepted design must satisfy not only the technical constraints mentioned above, but also to take into account the safe functioning of the installation, its ease of use, the personal safety of the operators and minimal operational costs.

All calculations are done using PLS-CADD as stipulated by the Technical Specifications.

The main elements of design presented in this document are sorted in the same manner as in the Technical Specification:

- Line Design
- Tower Design
- Foundations
- Conductor
- OPGW
- Insulators

Once approved by the Engineer, all further design documents shall be referred to this document.

2 LINE DESIGN

The Line Design philosophy is based on the limit state concept applied in conjunction with the partial factor method as specified in Section B2 - Particular Technical Requirements Article 2 of the Technical Specifications. Some of the parameters are repeated in this document only to emphasize.

2.1 Design Methodology

The reliability (probabilistic) approach in design loads and the concept of differentiated partial material factors, is applied as recommended by EN 50341-1-2012 and specified in the Section B2 - Particular Technical Requirements Article 2.4.3.

According to this concept the weighted resistances of the components concerned is checked against the ultimate (factored) actions applied to the Overhead Line components as illustrated below:

$$\mathbf{E_d} \quad \leq \quad \mathbf{R_d}$$

$$E_d \rightarrow \Sigma(\gamma_F \cdot F_K) \quad \leq \quad R_d = R_K / \gamma_M$$

The directly calculated physical loads are increased by partial safety factors whereas the resistances are divided by material factors in order to consider material strength uncertainties.

Load cases for all Overhead Line components are in accordance with EN 50341-1-2012 and specific conditions as per Technical Specification.

The respective Partial Factors for action and material strengths are in accordance with the Section C1&C2. Technical Schedules / Data Sheets.

In addition to the mechanical strength design, we took into consideration all geometrical constraints (electrical distances) specified by the Technical Specifications.

We used 220 kV double circuit tower family of towers corresponding for one climatic zone for Component B.2 and 110 kV double circuit 2 tower families of towers corresponding for two climatic zones for Component B.3 as described in Section B2 - Particular Technical Requirements Article 2.4.4 of this document. In case of the usage of these towers out of the specified limits, hereafter they shall be subject to a check of the mechanical strength and of the respect of the geometrical constraints (electrical distances) during spotting process.

In this document, results of optimization of the line design by means of site-specific line modelling using adjustments of design spans is presented.

2.2 Line Design Data

All design data are in accordance with Section B2 - Particular Technical Requirements Article 2.3.6 of the Technical Specifications, including the assumption of OPGW characteristics identical to Aluminum Conductor Steel Reinforced – ACS 95mm2 and ACS 120mm² allowing the Line design process.

The real characteristics of OPGW will be introduced in the final version of spotting realized using PLS-CADD, and the Line design will be reverified accordingly.

2.3 Sag and Tension Requirements

Conductor stringing are calculated based on the maximum tension/stress criteria mentioned in Section B2 - Particular Technical Requirements Article 2.6.2.5 of the Technical Specifications:

- EDS (everyday tension) condition:
  • At the yearly average temperature with no wind, the final horizontal tension/ stress shall not exceed 20% of the conductor breaking load.
- Maximum load condition for the following climatic loadings:
  • maximum design wind pressure, the final horizontal tension/ stress shall not exceed 45% of the conductor breaking load
  • minimum temperature, the final horizontal tension/ stress shall not exceed 45% of the conductor breaking load
  • maximum ice load with 40% of the maximum wind pressure, the final horizontal tension/ stress shall not exceed 50% of the conductor breaking load

OPGW stringing are calculated based on the maximum tension/stress criteria mentioned in Article 2.7.8 of Technical Specifications:

- EDS (everyday tension) condition:
  • At the yearly average temperature with no wind, the final horizontal tension/ stress shall not exceed 20% of the conductor breaking load
- Maximum load condition for the following climatic loadings:
  • maximum design wind pressure, the final horizontal tension/ stress shall not exceed 40% of the conductor breaking load
  • minimum temperature, the final horizontal tension/ stress shall not exceed 40% of the conductor breaking load
  • maximum ice load with 40% of the maximum wind pressure, the final horizontal tension/ stress shall not exceed 40% of the conductor breaking load

In addition, for the nominal span under every-day condition, the final OPGW sag shall not exceed 90% of the phase conductor sag.

We would like to highlight the limits of ruling span method in stringing because of terrain configuration and big differences in spans of the same section.

Traditional ruling span analysis may fail in case of changing conductor attachment elevations, in spans that differ in length from the ruling span, and in big elevation differences. This effect is even more evident in case of short spans adjacent to long spans and is to set adjacent span limitations in the line design criteria.

Finite element environment is much more accurate than the traditional ruling span design process and shall be used in PLS-CADD Line model.

The creep effect will be controlled using conductor supplier data or approved temperature shift method. Creep will be compensated by increasing the conductor tension at the time of stringing.

3 Tower Design

The Tower design is conditioned by geometry and mechanical strength of its components and effectuated using tower program, allowing three-dimensional indeterminate stiffness design method as specified in the Technical Specifications.

3.1 Tower Types

The design of the transmission line is based on the following family of towers as per the Technical Specifications:

Component B.2

- 22B-NS: normal suspension tower applicable for line deviation angles α = 0° - 2°
- 22B-LA: light angle and section tension tower applicable for line deviation angles α = 0° - 30° 1LA: light angle tower for line angles of up to 30° or 35°
- 22B-MA: medium angle tension tower applicable for line deviation angles α = 30° - 60°
- 22B-HA/DE: heavy angle tension tower applicable for line deviation angles α = 60° - 90° and for dead-end application with modified crossarms suitable for 0 to 45° angle in line direction and 0° to 45° angle of the slack span to the gantry and T-Off bifurcation at 90° from existing lines. As bifurcation function it shall allow T-Off derivation of either right circuit to the right side or of the left circuit to the left side.
- 22B-UGC: undercrossing structures (gantry type) to be used for undercrossing of the existing lines. They shall be designed as angle- tension structures applicable for line deviation angles 0 to 20 degrees measured towards adjacent towers. The gantries shall be designed as single or double circuit according to the specific conditions / restraints at each undercrossing position.

Component B.3

• Series A: for Zone 1 (altitudes above 1,500m, for an approximate line length of 25 km).
• Series B: for Zone 2 (altitudes below 1,500m, for an approximate line length of 22 km).

- 12A/B-NS: normal suspension tower applicable for line deviation angles α = 0° - 2°

- 12A/B-LC: angle tension tower to be used for large spans crossings, applicable for line deviation angles α = 0° - 10°. This type of tower shall have a wider range of body extensions and shall be designed for increased design spans.
- 12A/B-LA: light angle and section tension tower applicable for line deviation angles α = 0° - 30°
- 12A/B-MA: medium angle tension tower applicable for line deviation angles α = 30° - 60°
- 12A/B-HA/DE: heavy angle tension tower applicable for line deviation angles α = 60° - 90° and for dead-end application with modified crossarms suitable for 0 to 45° angle in line direction and 0° to 45° angle of the slack span to the gantry.
- 12A/B-HA/DET (to be provided only if needed in the Project, according to the detailed line route survey results): heavy angle tension tower applicable for line deviation angles 60 to 90 degrees, dead-end and T-Off bifurcation at 90° from existing lines.
- 12B-UGC (to be provided only if needed in the Project, according to the detailed line route survey results): Undercrossing structures (gantry type) to be used for undercrossing of the existing lines. They shall be designed as angle-tension structures applicable for line deviation angles 0 to 20 degrees measured towards adjacent towers. The gantries shall be designed as single or double circuit according to the specific conditions / restraints at each undercrossing position.

3.2 The Basic Tower Height (Height Under the Cross-arm)

The basic tower height (standard tower height with body extension ±0 and leg extension ±0) is determined considering the maximum conductor sag for the nominal span, the suspension insulator string length, and the minimum ground clearance as specified in the Technical Specifications.

Component B.2

Zone 2 (<1000m), "22B" Towers Family:

For suspension tower the basic tower height is:

$H_{sc} = F_c + D_s + L_c$

H_{sc} : Height under cross-arm

$H_{sc} = 15.5 + 7.4 + 3.2 = 26.1m$

F_c: Sag of the conductor at 75°C

F_c: 15.5m (see Section C1 Technical Data Sheets Section 5.2 of this document)

D_s: Distance to the ground

D_s = 7.4m (see Section C1 Technical Data Sheets Section 3.3.5 of this document)

L_c: Length of the suspension string

L_c = 3.2m

For the angle towers LA, LC, MA, HA/DE the basic tower height is:

$H_{sc} = F_c + D_s$

$H_{sc} = 15.5 + 7.4 = 22.9m$

Component B.3

Zone 1 (>1500m), "12A" Towers Family:

For suspension tower the basic tower height is:

$H_{sc}= F_c + D_s + L_c$

$H_{sc:}$ Height under cross-arm

H_{sc}=13.5 + 7.5 + 2.1 = 23.1m

F_c: Sag of the conductor at 75°C

F_c: 13.5m (see Section C2 Technical Data Sheets Section 5.2 of this document)

D_s: Distance to the ground

D_s = 7.5m (see Section C2 Technical Data Sheets Section 3.3.5 of this document)

L_c: Length of the suspension string

L_c = 2.1m

For the angle towers LA, LC, MA, HA/DE the basic tower height is:

$H_{sc}= F_c + D_s$

H_{sc}= 13.5 + 7.5 = 21m

Zone 1 (>1500m), "12A" Towers Family:

For suspension tower the basic tower height is:

$H_{sc}= F_c + D_s + L_c$

$H_{sc:}$ Height under cross-arm

H_{sc}=14.4 + 7.0 + 2.1 = 23.5m

F_c: Sag of the conductor at 75°C

F_c: 14.4m (see Section C2 Technical Data Sheets Section 5.2 of this document)

D_s: Distance to the ground

D_s = 7.0m (see Section C2 Technical Data Sheets Section 3.3.5 of this document)

L_c: Length of the suspension string

L_c = 2.1m

For the angle towers LA, LC, MA, HA/DE the basic tower height is:

$H_{sc}= F_c + D_s$

H_{sc}= 14.4 + 7.0 = 21.4m

3.3 Tower Body and Leg Extensions

Tower body and legs extensions considered in the design are in accordance with Section B2 - Particular Technical Requirements Article 2.4.6 of the Technical Specifications.

Tower type		NS	LC	LA	MA	HA/DE
Body Extensions (meters)	from:	-3	-3	-3	-3	-3
	in step of:	3	3	3	3	3
	to:	12	+15(*)	9	6	6
Leg Extensions (meters)	from:	-3	-3	-3	-3	-3
	in step of:	1.5	1.5	1.5	1.5	1.5
	to:	6	6	6	6	6

(*) Additional Body Extension of (+15 m) may be considered for LC tower design, if it will be required following the results of the detailed line survey.

If any other extension/reduction is needed during the spotting, it shall be subject to specific design. The required extension/reduction shall be calculated only for this particular case.

3.4 Geometry of The Tower Heads

The clearances between live and earthed parts determining tower head geometry are considered in a different way for the different clearance cases and swing angles, corresponding to the three voltage stress types (lightning, switching and power frequency) as indicated in Section C1&C2 - Technical Data Sheets Subsection 3.3 Technical Specifications:

Component B.2

Minimum clearances between phase conductors, D_{pp}:	Unit	Data
• In still air	m	2.7
• Under moderate wind (3 years return period)	m	2.1
• Under maximum wind (50 years return period)	m	0.7
Minimum clearance between live parts and earthed parts, Del:		
• In still air	m	2.4
• Under moderate wind (3 years return period)	m	1.8
• Under maximum wind (50 years return period)	m	0.5

Component B.3

Minimum clearances between phase conductors, D_{pp}:	Unit	Data
• In still air	m	1.7 / 1.5
• Under moderate wind (3 years return period)	m	1.3 / 1.2
• Under maximum wind (50 years return period)	m	0.5 / 0.4
Minimum clearance between live parts and earthed parts, Del:		
• In still air	m	1.5 / 1.4
• Under moderate wind (3 years return period)	m	1.2 / 1.1
• Under maximum wind (50 years return period)	m	0.4 / 0.3

The dimensions of the cross-arms of the angle-tension towers are such to ensure that horizontal spacing between conductors in a plan normal to the conductors are not less than that of normal suspension towers. The OPGW support positions are ensuring the corresponding spacing between OPGW wires as well as the shielding angle of 20° as per the Technical Specifications.

The phase-to-phase and phase-to-earthwire mid span clearances determine the maximum span of the respective tower.

The maximum span limited by two different tower types is the average of the maximum spans of the two towers.

Horizontal offset of bottom crossarm is to avoid impact of falling ice from the arm above. Due significant vertical distance all arms can be of same length.

3.5 Load Cases

The calculation of loads applied to the towers shall be done in compliance with:

- Technical Specifications
- EN 50341-1-2012

The wind loads on the line equipment and tower shall be calculated based on the basic wind velocity factored for the respective height above ground in accordance with EN 50341-1-2012, Chapter 4.3. All calculation of loads shall be done using PLS-CADD and transmitted in automatic way to TOWER program for geometrical (cable swinging) and mechanical strength verification.

The loading cases considered for the design of the line supports and of their foundations are climatic loading cases, security loading cases, erection and maintenance loading cases, as follows:

Climatic loading cases:

- Wind loads (sub-designations C1&C2: maximum (peak) wind pressure acting in both transverse and oblique at 45° direction)
- Uniform ice load
- Combined wind and ice loads (sub-designations C3&C4: maximum ice loading combined with 40% of maximum (peak) wind pressure acting in both transverse and oblique at 45° direction, C5&C6: maximum (peak) wind pressure acting in transverse and oblique 45° direction)
- Combined wind and ice loads - unbalanced (sub-designation C7) - Anti Cascading

Security loading cases:

- Torsional and Longitudinal - broken wire - loads (SC1)
- Longitudinal Loads (SC2) - anti-cascading

Safety loading cases:

- Erection and Maintenance Loads
- Loads due to the weight of linesmen

Security loading cases (SC1, SC2) shall be applied as outlined in Technical Specification, Section 2.4.10.2. The provision of Article 4.8.4 of EN 50341-1:2012 related to determination of maximum longitudinal forces acting on the remaining conductor or OPGW shall be applied.

Erection and maintenance loads shall be part of verification of tower mechanical characteristics. The Contractor shall prepare working procedures to avoid overstressing of supports as specified in the Technical Specifications and EN 50341-1-2012 article 4.9.1

3.6 Partial Safety Factors for Actions

The partial factors for actions shall be in accordance with the Technical Data Sheets, Article 3.1.

Partial factors for actions (γF)	Data
For permanent actions: dead weight of conductors, OPGW, insulator sets, towers, for all loading cases (γG)	1.1 (when stress increasing) and 1.0 (when stress decreasing)
For variable actions / climatic loadings: wind(γW), ice (γI) and conductors tension (γC), for towers, foundations, insulators, hardware and fittings, applicable as following:	
For normal loading cases N1...N5: γW, γI, γC	1.35
For exceptional loading cases E1, E2: γC,γI	1.1
For construction and maintenance loading case E3: γW, γC	1.5
For dynamic stringing loading: γC	2

3.7 Partial Safety Factors for Material

The partial factors for material shall be in accordance with Technical Data Sheets Article 3.2.

Partial factors for material (γM)	Data
Towers:	
Structural steel sections in compression, buckling	1.1
Bolted or welded joints	1.25
Bolts and structural steel sections in tension	1.25

3.8 Mechanical Properties of Used Materials

3.8.1 Steels

The Contractor have chosen two sorts of steel for the tower construction, as specified in the Technical Specifications.

The mechanical properties of used steels shall be in conformance with EN 10025 or equivalent.

Mild Steel S235J2 F_y = 2350 daN/cm²

High-quality Steel S355J2 F_y = 3550 daN/cm²

Where: F_u = Ultimate tensile stress

F_y = Yield stress

3.8.2 Bolts

The mechanical properties of used bolts shall be in conformance with ISO 898-1 and -2

Class 5.6 F_{ub} = 5000 daN/cm²
Class 8.8 F_{ub} = 8000 daN/cm²

Where: F_{ub} = Ultimate tensile stress of bolt material

3.9 Ultimate stresses

The ultimate stresses for the different stress categories are taken from EN 50341-1-2012, Annex J (Lattice Steel Supports):

Component/Action	Characteristic Resistance
Members: Compression Tension on Net Section	 see chapter 3.10 of this document $0.9\ F_y \cdot A_{net} / g_{M1}$
Bolted Connections: Bolts in shear Bolts in bearing	 $0.6 \cdot F_{ub} \cdot A / g_{M2}$ $\alpha \cdot F_u \cdot d \cdot t / g_{M2}$

where α is 1.91, the smallest value of:

3 ; $1.20(e_1/d_0)$; $1.85(e_1/d_0-0.5)$; $0.96(P_1/d_0-0.5)$; $2.3(e_2/d_0-0.5)$ and reduction factor of 1.0 as default value

In accordance with table J.3. of section J.5 of Annex J of EN 50341-1:2012 and Table 5.1 of Technical specifications

3.10 Check of the Buckling Resistance of Members

The following design procedure shall be in accordance with EN 50341-1-2012, chapter J.4:

- The appropriate buckling curve used is the curve b from 5.5.1 of ENV 1993-1-1
- The appropriate slenderness ratio λ is determined according to J.4 of EN 50341-1-2012 (without changing the boxed values).
- The non-dimensional slenderness ratio λ for the relevant buckling load in equation 5.4.6. of EN 1993-1-1 is replaced by the effective slenderness λ_{eff} determined from clauses J.4.1 and J.4.2 of EN 50341-1:2012.
- The reduction factor χ is calculated using formula 5.46 in EN 1993-1-1.

We used US Standard ASCE 10-90 to check design of towers given by buckling formulas:

$$F_a = \left[1 - \frac{1}{2} \cdot \left(\frac{KL/r}{C_c}\right)^2\right] \cdot F_y; \quad \frac{KL}{r} \le C_c$$

$$F_a = \frac{\pi^2 \cdot E}{\left(KL/r\right)^2}; \quad \frac{KL}{r} \ge C_c$$

$$C_c = \pi \cdot \sqrt{\frac{2 \cdot E}{F_y}}$$

Main member .... $\frac{KL}{r} = \frac{L}{r}$

Cross-arm main members .... $\frac{KL}{r} = 30 + 0.75\ \frac{L}{r}$

Other members:

- 1 < (L/r) < 120: $\frac{KL}{r} = 60 + 0.50\ \frac{L}{r}$
- 120 < (L/r) < 200: $\frac{KL}{r} = \frac{L}{r}$

F_y - Limit of elasticity

F_y - Mild steel .... 2350 daN/cm²

F_y - High tensile steel.... 3550 daN/cm²

E - Module of elasticity

E = 2060000 daN/cm²

4 CONDUCTOR

Conductor configuration shall be in accordance with Technical Specifications:

- Component B.2: single phase conductor (1)
  - 1 x ACSR 400/51
- Component B.3: single phase conductor (1):
  - below 1,500 m amsl: 1 x ACSR 240/32
  - above 1,500 m amsl and for long spans: 1 x ACSR 240/56

The sag and tension calculation of conductor shall be produced for the load cases described in the Technical Specifications. The values of the maximum stress of the conductors can support under various loads shall be within the limits specified by the Technical Specifications EDS ≤ 20%UTS.

The characteristics of the conductor used in the following calculations shall be taken from the technical file provided by the conductor manufacturer.

Ruling Span Sag Tension Report (220 kV)

Weather Case Description	Cable Load Hor. Load (daN/m)	Cable Load Vert Load (daN/m)	Cable Load Res. Load (daN/m)	R.S. Final Cond. After Creep Max. Tens. (daN)	R.S. Final Cond. After Creep Hori. Tens. (daN)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (m)	R.S. Final Cond. After Creep R.S. Sag (m)
EDS	0.00	1.43	1.43	2182	2163	18	1509	13.27
Max. Wind	2.20	1.43	2.62	3788	3751	31	1431	14.00
Wind & Ice C1	2.16	3.48	4.10	5596	5536	46	1352	14.83
Wind & Ice C2	2.63	2.15	3.40	4814	4765	40	1401	14.30
Ice	0.00	3.48	3.48	4908	4858	41	1395	14.36
Min. Temp.	0.00	1.43	1.43	2528	2511	21	1752	11.43
Max. Cond. Temp.	0	1.43	1.43	1875	1853	16	1293	15.50

Maximum sag in case of maximum temperature and Ruling span after creep is 15.50m

Maximum sag in case of everyday service condition and Ruling span after creep is 13.27m

Ruling Span Sag Tension Report (110 kV-Zone 1)

Weather Case Description	Cable Load Hor. Load (daN/m)	Cable Load Vert Load (daN/m)	Cable Load Res. Load (daN/m)	R.S. Final Cond. After Creep Max. Tens. (daN)	R.S. Final Cond. After Creep Hori. Tens. (daN)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (m)	R.S. Final Cond. After Creep R.S. Sag (m)
EDS (Zone 1)	0	1.08	1.08	942	929	10	856	11.89
Max. Wind (Zone 1)	2.93	1.08	3.13	2530	2490	26	796	12.78
Wind & Ice C1 (Zone 1)	4.52	4.84	6.63	5003	4912	50	741	13.74
Wind & Ice C2 (Zone 1)	5.13	2.4	5.66	4372	4296	44	759	13.42
Ice (Zone 1)	0	4.84	4.84	3819	3755	39	776	13.12
Min. Temp. (Zone 1)	0	1.08	1.08	1026	1014	10	935	10.88
Max. Cond. Temp.	0	1.08	1.08	833	819	8	754	13.50

Maximum sag in case of maximum temperature and Ruling span after creep is 13.50m

Maximum sag in case of everyday service condition and Ruling span after creep is 11.89m

Ruling Span Sag Tension Report (110 kV-Zone 2)

Weather Case Description	Cable Load Hor. Load (daN/m)	Cable Load Vert Load (daN/m)	Cable Load Res. Load (daN/m)	R.S. Final Cond. After Creep Max. Tens. (daN)	R.S. Final Cond. After Creep Hori. Tens. (daN)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (m)	R.S. Final Cond. After Creep R.S. Sag (m)
EDS (Zone 2)	0	0.9	0.9	907	895	12	991	12.94
Max. Wind (Zone 2)	1.8	0.9	2.02	1964	1937	26	960	13.36
Wind & Ice C1 (Zone 2)	2.39	3.42	4.17	3814	3754	50	900	14.26
Wind & Ice C2 (Zone 2)	2.78	1.8	3.31	3118	3072	42	928	13.83
Ice (Zone 2)	0	3.42	3.42	3204	3157	43	924	13.89
Min. Temp. (Zone 2)	0	0.9	0.9	997	986	13	1092	11.75
Max. Cond. Temp.	0	0.9	0.9	818	805	11	891	14.40

Maximum sag in case of maximum temperature and Ruling span after creep is 14.40m

Maximum sag in case of everyday service condition and Ruling span after creep is 12.94m

5 OPGW

The sag and tension calculation of fiber-optic earthwire shall be produced for the load cases described in the Technical Specifications.

The characteristics of the OPGW used in the following calculations are taken from the technical file are assumed to be identical as for ACS 120 mm² (110 kV-Zone1), ACS 95 mm2 (110 kV-Zone2 and 220 kV). The real characteristics of OPGW shall be included in spotting verification upon final approval of OPGW manufacturer.

Ruling Span Sag Tension Report (110 kV-Zone 1)

Weather Case Description	Cable Load Hor. Load (daN/m)	Cable Load Vert Load (daN/m)	Cable Load Res. Load (daN/m)	R.S. Final Cond. After Creep Max. Tens. (daN)	R.S. Final Cond. After Creep Hori. Tens. (daN)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (m)	R.S. Final Cond. After Creep R.S. Sag (m)
EDS (Zone 1)	0	0.79	0.79	756	748	5	951	10.70
Max. Wind (Zone 1)	2.33	0.79	2.46	2164	2135	13	866	11.74
Wind & Ice C1 (Zone 1)	5.03	4	6.43	4978	4892	30	761	13.38
Wind & Ice C2 (Zone 1)	5.36	1.83	5.67	4488	4413	27	779	13.07
Ice (Zone 1)	0	4	4	3355	3306	21	826	12.32
Min. Temp. (Zone 1)	0	0.79	0.79	810	802	5	1020	9.97
Max. OPGW Temp.	0	0.79	0.79	717	708	4	900	11.30

Maximum sag in case of everyday service condition and no wind is 10.70m which is 10.70/11.89 = 90% of the phase conductor sag as specified in Technical Specifications.

Ruling Span Sag Tension Report (110 kV-Zone 2)

Weather Case Description	Cable Load Hor. Load (daN/m)	Cable Load Vert Load (daN/m)	Cable Load Res. Load (daN/m)	R.S. Final Cond. After Creep Max. Tens. (daN)	R.S. Final Cond. After Creep Hori. Tens. (daN)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (m)	R.S. Final Cond. After Creep R.S. Sag (m)
EDS (Zone 2)	0	0.59	0.59	661	654	6	1101	11.64
Max. Wind (Zone 2)	1.38	0.59	1.5	1559	1541	14	1029	12.47
Wind & Ice C1 (Zone 2)	2.57	2.68	3.71	3403	3350	30	903	14.22
Wind & Ice C2 (Zone 2)	2.78	1.28	3.06	2907	2865	26	936	13.72
Ice (Zone 2)	0	2.68	2.68	2599	2563	23	958	13.4
Min. Temp. (Zone 2)	0	0.59	0.59	723	717	6	1207	10.62
Max. OPGW Temp.	0	0.59	0.59	633	625	6	1053	12.18

Maximum sag in case of everyday service condition and no wind is 11.64m which is 11.64/12.94 = 90% of the phase conductor sag as specified in Technical Specifications.

Ruling Span Sag Tension Report (220 kV)

Weather Case Description	Cable Load Hor. Load (daN/m)	Cable Load Vert Load (daN/m)	Cable Load Res. Load (daN/m)	R.S. Final Cond. After Creep Max. Tens. (daN)	R.S. Final Cond. After Creep Hori. Tens. (daN)	R.S. Final Cond. After Creep Max Ten %UL	R.S. Final Cond. After Creep C (m)	R.S. Final Cond. After Creep R.S. Sag (m)

EDS	0	0.59	0.59	1003	996	9	1677	11.94
Max. Wind	1.35	0.59	1.47	2183	2163	19	1468	13.65
Wind & Ice C1	2.13	2.04	2.95	3794	3748	34	1271	15.77
Wind & Ice C2	2.28	1.04	2.5	3351	3313	30	1324	15.14
Ice	0	2.04	2.04	2869	2840	26	1390	14.42
Min. Temp.	0	0.59	0.59	1139	1132	10	1906	10.5
Max. OPGW Temp.	0	0.59	0.59	712	702	6	1182	16.96

Maximum sag in case of everyday service condition and no wind is 11.94m which is 11.94/13.27 = 90% of the phase conductor sag as specified in Technical Specifications.

6 Insulators Sets

The insulators shall be in accordance with Section 10 of EN 50341-1:2012.

Complete insulator sets consisting of composite insulator units and assembling fittings as well as fittings for phase conductors and OPGW shall be in accordance with Technical Schedules/Data Sheets.

All details concerning all complete insulator sets and their components shall be described in the supplier's documents.

The Contractor shall adopt the length of double suspension string of 3.2m for Component B.2 and 2.1m for Component B.3 design purposes.