SEK SVENSK ELSTANDARD

SVENSK STANDARD

SS-EN 50341-2-18, utg 2:2023

Fastställd	Sida	Ansvarig kommitté
2023-09-20	1 (93)	SEK TK 11

Elektriska friledningar över 1 kV (AC) –
Del 2-18: Svensk normativ bilaga

Overhead electrical lines exceeding AC 1 kV –
Part 2-18: National Normative Aspects (NNA) for Sweden (based on EN 50341-1:2012)

Som svensk standard gäller europastandarden EN 50341-2-18:2023. Den svenska standarden innehåller den officiella engelska språkversionen av EN 50341-2-18:2023.

Nationellt förord

Tidigare fastställd svensk standard SS-EN 50341-2-18, utg 1:2017 med eventuella tillägg, ändringar och rättelser gäller ej fr o m 2026-03-22.

ICS 29.240.20

Denna standard är fastställd av SEK Svensk Elstandard,
som också kan lämna upplysningar om **sakinnehållet** i standarden.
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Standarder underlättar utvecklingen och höjer elsäkerheten

Det finns många fördelar med att ha gemensamma tekniska regler för bl a mätning, säkerhet och provning och för utförande, skötsel och dokumentation av elprodukter och elanläggningar.

Genom att utforma sådana standarder blir säkerhetsfordringar tydliga och utvecklingskostnaderna rimliga samtidigt som marknadens acceptans för produkten eller tjänsten ökar.

Många standarder inom elområdet beskriver tekniska lösningar och metoder som åstadkommer den elsäkerhet som föreskrivs av svenska myndigheter och av EU.

SEK är Sveriges röst i standardiseringsarbetet inom elområdet

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Stora delar av arbetet sker internationellt

Utformningen av standarder sker i allt väsentligt i internationellt och europeiskt samarbete. SEK är svensk nationalkommitté av International Electrotechnical Commission (IEC) och Comité Européen de Normalisation Electrotechnique (CENELEC).

Standardiseringsarbetet inom SEK är organiserat i referensgrupper bestående av ett antal tekniska kommittéer som speglar hur arbetet inom IEC och CENELEC är organiserat.

Arbetet i de tekniska kommittéerna är öppet för alla svenska organisationer, företag, institutioner, myndigheter och statliga verk. Den årliga avgiften för deltagandet och intäkter från försäljning finansierar SEKs standardiseringsverksamhet och medlemsavgift till IEC och CENELEC.

Var med och påverka!

Den som deltar i SEKs tekniska kommittéarbete har möjlighet att påverka framtida standarder och får tidig tillgång till information och dokumentation om utvecklingen inom sitt teknikområde. Arbetet och kontakterna med kollegor, kunder och konkurrenter kan gynnsamt påverka enskilda företags affärsutveckling och bidrar till deltagarnas egen kompetensutveckling.

Du som vill dra nytta av dessa möjligheter är välkommen att kontakta SEKs kansli för mer information.

SEK Svensk Elstandard
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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50341-2-18

May 2023

ICS 29.240.20

Supersedes EN 50341-2-18:2016

English Version

Overhead electrical lines exceeding AC 1 kV - Part 2-18: National Normative Aspects (NNA) for Sweden (based on EN 50341-1:2012)

Lignes électriques aériennes dépassant 1 kV en courant alternatif - Partie 2-18 : Aspects Normatifs Nationaux (NNA) pour la Suède (sur la base de l'EN 50341-1:2012)

This European Standard was approved by CENELEC on 2023-03-22. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN 50341-2-18:2023 E

Foreword

1 The Swedish National Committee (NC) is identified by the following address:

SEK Svensk Elstandard - TK11 Overhead Lines
Box 1284
SE-164 29 KISTA
Telephone no.: +46 8 444 14 00
E-mail sek@elstandard.se

2 The Swedish NC has prepared this Part 2-18 of EN 50341, listing the Swedish national normative aspects (NNA), under the sole responsibility, and duly passed it through the CENELEC and CLC/TC 11 procedures.

NOTE The Swedish NC also takes the sole responsibility for the technically correct co-ordination of this EN 50341-2-18 with EN 50341. It has performed the necessary checks in the frame of quality assurance/control. It is noted however that this quality assurance/control has been made in the framework of the general responsibility of a standard committee under the national laws/regulations.

3 This NNA is normative in Sweden and informative in other countries.

4 This NNA has to be read in conjunction with Part 1 (EN 50341-1). All clause numbers used in this NNA correspond to those of Part 1. Specific subclauses, which are prefixed "SE", are to be read as amendments to the relevant text in Part 1. Any necessary clarification regarding the application of this NNA in conjunction with Part 1 shall be referred to the Swedish NC who will, in co-operation with CLC/TC 11 clarify the requirements.

When no reference is made in this NNA to a specific subclause, then Part 1 applies.

5 In the case of "boxed values" defined in Part 1, amended values (if any), which are defined in this NNA shall be taken into account in Sweden.

However, any boxed value, whether in Part 1 or in this NNA, shall not be amended in the direction of greater risk in a Project Specification.

6 The national Swedish standards / regulations related to overhead electrical lines exceeding 1 kV (AC) are listed in subclause 2.1/SE

NOTE All national standards referred to in this NNA will be replaced by the relevant European Standards as soon as they become available and are declared by the Swedish NC to be applicable and thus reported to the secretary of CLC/TC 11.

1 Scope

(ncpt)

SE.1 Application to existing overhead lines

This Part 2-18 is applicable for new overhead lines only and not for existing lines.

(A-dev)

SE.2 Maintenance, rebuilding or extension of an overhead line

Measures related to maintenance of the electrical installation shall fulfill the legislation in force when it was erected. In the case of a rebuilding or extension of an electrical installation (overhead line), the current regulations in force shall be applied for the rebuilding or extension.

(Regulations and general advice of the National Electrical Safety Board regarding the installation of electrical installations ”Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda”, Ikraftträdande och övergångsbestämmelser (ELSÄK-FS 2022:1))

(ncpt)

SE.3 Optical ground wire (OPGW) and optical phase conductor (OPCON)

This Part 2-18 is applicable for installation of OPGW and OPCON, also known as OPPC, in overhead lines in Sweden.

(ncpt)

SE.4 All dielectric self supporting optical cable (ADSS) and optical attached cable (OPAC)

This Part 2-18 is applicable for installation of ADSS and OPAC in overhead lines in Sweden.

NOTE The allowable electrical field for the ADSS cable should be taken into consideration when the conductor configuration is determined.

2 Normative references, definitions and symbols

2.1 Normative references

(A-dev)

SE.1 National normative laws, government regulations

Reference	Title
ELSÄK-FS 2011:3	Elsäkerhetsverkets föreskrifter om ansökan om drifttillstånd *Regulations of the National Electrical Safety Board regarding application for operating permit*
ELSÄK-FS 2022:1	Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda *Regulations and general advice of the National Electrical Safety Board regarding the installation of electrical installations*
ELSÄK FS 2022:3	Elsäkerhetsverkets föreskrifter och allmänna råd om innehavarens kontroll av starkströmsanläggningar och elektriska utrustningar *The regulations and general advice of the National Electrical Safety Board regarding checks of electrical installations and electrical equipment by the holder*
SFS 2017:218	Elsäkerhetsförordning *The Swedish Government - Ordinance concerning electrical safety*
BFS 2011:10 - EKS	Boverkets föreskrifter och allmänna råd om tillämpning av europeiska konstruktionsstandarder (eurokoder) *Swedish National Board of Housing, Building and Planning: Application of the European design standards*

NOTE If there is associated amendment instructions to the documents listed above, they shall be included.

(ncpt)

SE.2 National normative standards referred to in this NNA

Reference	Title
SS-EN 335:2013	Träskydd - Definitioner och tillämpning av användningsklasser - Massivt trä och träbaserade produkter *Durability of wood and wood-based products — Use classes: definitions, application to solid wood and wood-based products*
SS-EN 351-1:2007	Träskydd – Träskyddsbehandlat massivt trä – Del 1: Klassificering och upptagning av träskyddsmedel *Durability of wood and wood-based products – Preservative-treated solid wood – Part 1: Classification of preservative penetration and retention*
SS-EN ISO 527-2:2012	Plast - Bestämning av töjningsegenskaper - Del 2: Provningsbetingelser för press- och sprutmassa (ISO 527-2:2012) *Plastics -- Determination of tensile properties -- Part 2: Test conditions for moulding and extrusion plastics*
SS-EN ISO 527-3:2018	Plast - Bestämning av draghållfasthet - Del 3: Provningsbetingelser för filmer och Skivor (ISO 527-3:2018) *Plastics -- Determination of tensile properties -- Part 3: Test conditions for films and sheets*

Reference	Title
SS-ISO 965-4:2021	Metriska ISO-gängor för allmän användning – Gängtoleranser - Del 4: Gränsmått för varmförzinkade utvändiga gängor avsedda för användning tillsammans med invändiga gängor gängade till toleranskvalitet H eller G efter förzinkning *ISO general purpose metric screw threads - Tolerances - Part 4: Limits of sizes for hot-dip galvanized external screw threads to mate with internal screw threads tapped with tolerance position H or G after galvanizing*
SS-EN 1090-2:2018	Utförande av stål- och aluminiumkonstruktioner – Del 2: Stålkonstruktioner *Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures*
SS-EN 1999-1-1:2007	Eurokod 9 : Dimensionering av aluminiumkonstruktioner – Del 1-1: Allmänna regler *Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules*
SS-EN ISO 4892-2:2013	Plast - Metoder för exponering i artificiellt ljus - Del 2: Xenon-arc ljuskällor (ISO 4892-2:2013) *Plastics -- Methods of exposure to laboratory light sources -- Part 2: Xenon-arc lamps*
SS-EN ISO 4892-3:2016	Plast - Metoder för exponering i artificiellt ljus - Del 3: UV lysrör (ISO 4892-3:2016) *Plastics - Methods of exposure to laboratory light sources - Part 3: Fluorescent UV lamps (ISO 4892-3:2016)*
SS-EN 10164:2018	Stålprodukter med förbättrade deformationsegenskaper i tjockleksriktningen - Tekniska leveransbestämmelser *Steel products with improved deformation properties perpendicular to the surface of the product - Technical delivery conditions*
SS-EN 10204:2005	Metalliska varor - Typer av kontrolldokument *Metallic products - Types of inspection documents*
SS-EN ISO 10684:2004	Fästelement – Varmförzinkning av fästelement *Fasteners – Hot dip galvanized coatings*
SS-EN 13670:2009	Betongkonstruktioner – Utförande *Execution of concrete structures*
SS-EN 60060	Högspänningsprovning *High-voltage test techniques*
SS 424 05 02	Isolatorer – Stödisolatorer av pinntyp för friledningar *Insulators – Pin insulators for overhead lines*
SS 424 05 21	Stödisolator av massiv typ för friledningar *Line post insulators*
SS 424 05 31	Isolatorer - Stagisolatorer *Insulators - Stay insulators*
SS 424 08 06	Linor av hård förzinkad ståltråd för luftledningar - Fe140-linor *Hard zinc-coated steel wire strands for overhead lines – Fe140 wire strands*
SS 424 08 11	Tråd av aluminiumlegering för linor för friledningar - AlMgSi-tråd *Aluminium alloy wire for stranded conductors for overhead line – AlMgSi wire*
SS 424 08 12	Linor av aluminiumlegering för friledningar – AlMgSi-linor *Aluminium alloy stranded conductors for overhead line – AlMgSi-conductor*

Reference	Title
SS 424 08 13	Tråd av aluminiumlegering för linor för friledningar - Al 59-tråd *Aluminium alloy wire for stranded conductors for overhead line – Al 59 wire*
SS 424 08 14	Linor av aluminiumlegering för friledningar - Al 59-linor *Aluminium alloy stranded conductors for overhead line – Al 59-conductor*
SS 424 12 50	Najning *Ties*
SS 424 12 51	Förformad najningsspiral *Preformed ties*
SS 436 02 61	Luftledningskorsningar - Högspänningsledning (friledning), högst 52 kV, över allmän väg *Overhead line crossings - High voltage overhead line for max 52 kV above public road*
SS 436 02 62	Luftledningskorsningar - Högspänningsledning (friledning), högst 52 kV, över allmän väg - Trädsäkert korsningsspann *Overhead line crossings - High voltage overhead line for max 52 kV above public road - Crossing span safe for falling trees*
SS 436 02 63	Luftledningskorsningar - Högspänningsledning (friledning), högst 52 kV, över järnväg - Trädsäkert korsningsspann *Overhead line crossings - High voltage overhead line for max 52 kV above railway - Crossing span safe for falling trees*
SS 436 02 65	Luftledningskorsningar - Högspänningsledning (hängspiralkabel utan skärm), 1-24 kV, över allmän väg *Overhead line crossings - High voltage overhead line (self-supporting aerial cable without shield) 1-24 kV above public road*
SS 436 02 66	Luftledningskorsningar - Högspänningsledning (hängspiralkabel utan skärm), 1-24 kV, över järnväg *Overhead line crossings - High voltage overhead line (self-supporting aerial cable without shield) 1-24 kV above railway*
SS 436 02 80	Luftledningskorsningar - Högspänningsledning (metallskärmad hängkabel eller metallskärmad hängspiralkabel), 1-24 kV, över allmän väg *Overhead line crossings - High voltage overhead line (suspension cable with metal sheath) 1-24 kV above public road*
SS 436 02 81	Luftledningskorsningar - Högspänningsledning (metallskärmad hängkabel eller metallskärmad hängspiralkabel), 1-24 kV, över järnväg *Overhead line crossings - High voltage overhead line (suspension cable with metal sheath) 1-24 kV above railway*

(ncpt)

SE.3 National informative documents referred to in this NNA

Reference	Title
NTR Dokument 3: 2017	Nordiska Träskyddsrådet – Nordiska regler för kvalitetskontroll av impregnerat trä – Del 1: Träskyddsbehandlad furu och andra lätt impregnerbara barrträslag *The Nordic Wood Preservation Council – Nordic requirements for quality control of industrially protected wood – Part 1: Scots pine and other permeable softwoods*
Korrosionsinstitutet Bulletin nr 97	Riktlinjer för användning av rostträga stål - Korrosionstekniska synpunkter *Guidelines for use of weathering steel - Corrosion technical aspects*
Korrosionsinstitutet Bulletin No. 94	Rostträga stål i byggnader *Weathering steel in buildings*

2.2 Definitions

(A-dev)

SE.1.1 Reinforced lines type 1

Overhead lines so designed that the forces which according to experience is expected to occur do not inflict damage which adversely will affect the capability of these lines or imply hazard to persons or property.

(Regulations and general advice of the National Electrical Safety Board regarding the installation of electrical installations ”Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda”, Brottsäker ledning: 6 kap. 1, 10 and 11 §§, (ELSÄK-FS 2022:1)).

(A-dev)

SE.1.2 Reinforced lines type 2

Design of overhead line within the nominal voltage of 1-25 kV in urban area with reliability level 2, efficient earth fault protection and particular measures to reduce the risk of falling trees.

(Regulations and general advice of the National Electrical Safety Board regarding the installation of electrical installations ”Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda”, Ledning i förstärkt utförande: 5 kap. 5 § and 6 kap. 1 and 11 §§ (ELSÄK-FS 2022:1)).

(A-dev)

SE.2.1 Urban areas

Areas covered by a detailed development plan.

(”Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda”, Område med detaljplan: 5 kap. 6 § and 6 kap. (ELSÄK-FS 2022:1))

(A-dev)

SE.2.1 Rural areas

Areas not covered by a detailed development plan

(”Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda”, Område utan detaljplan: 5 kap. 6 § and 6 kap. (ELSÄK-FS 2022:1))

(ncpt)

SE.3 Similar conductors

Similar conductors are conductors which have the same cross section, material, sag and attachment, see also Table 5.8/SE.1.

(ncpt)

SE.4 Demarcation span

Single spans which separate a line section build as a reinforced line type 1 with timber pole support and with highest system voltage equal to or less than 55 kV. The demarcation span shall be supported by demarcation supports which are timber pole supports without longitudinal guys.

2.3 Symbols

(ncpt)

SE.1

Symbol	Signification	Reference
E_i	Modulus of elasticity, initial stage (before ice load)	9.6.4/SE.1
E_{iL}	Modulus of elasticity, initial lower	9.6.4/SE.1
E_{iU}	Modulus of elasticity, initial upper	9.6.4/SE.1
E_p	Modulus of elasticity, final stage (after ice load)	9.6.4/SE.1
f_{ctm}	Mean value of axial tensile strength of concrete	7.6.5/SE.1
g_e	Dead weight of the conductor	4.5.2/SE.1 to SE.2
g_{i0}	Ice-load at no wind	4.5.2/SE.1 to SE.2
g_{iw}	Ice-load at normal wind	4.5.2/SE.1 to SE.2
g_{w0}	Normal wind load at bare conductor	4.5.2/SE.1 to SE.2
g_{wi}	Normal wind-load at conductor covered by ice load	4.5.2/SE.1 to SE.2
H	Horizontal clearance	Table 5.8/SE.1 to SE.2
h	Horizontal clearance at mixed conductor configuration, height above ground	Table 5.8/SE.1 to SE.2, 4.3
k	Voltage coefficient for distances	Table 5.8/SE.1 to SE.3
S	Voltage dependent distance	5.9.1/SE.1
U_{SK}	Lightning impulse withstand voltage	5.5/SE.1 to SE.2.2
U_{SL}	Switching impulse withstand voltage	5.5/SE.1 to SE.2.2
U_V	Short duration wet power frequency withstand voltage	5.5/SE.1 to SE.2.2
V	Vertical clearance	Table 5.8/SE.1 to SE.2
v	Vertical clearance at mixed conductor configuration	Table 5.8/SE.1 to SE.2
W	Free space, from high water level, for sailing, given by the authorities	Table 5.9.4/SE.2
X	Clearance between conductors, factor in conductor calculation	Table 5.8/SE.3, 9.6.4/SE.1
ε_c	Strain elongation due to creep	9.6.4/SE.1
ε_s	Strain elongation due to stress	9.6.4/SE.1
σ	Stress value	9.6.4/SE.1
σ_0	Stress value in conductor at 0 °C	9.6.4/SE.1
σ_p	Highest stress value at which E_{iL} is valid	9.6.4/SE.1

3 Basis of design

3.2 Requirements of overhead lines

3.2.2 Reliability requirements

(A-dev)

SE.1.1 Reliability level 2

Reliability level 2 with partial factors in accordance with 4.13 of this NNA shall be used for overhead lines of class A in Sweden for which this NNA is applicable.

(ncpt)

SE.1.2 Reliability level 1

Reliability level 1 with partial factors in accordance with 4.13 of this NNA shall be used for overhead lines of class B in Sweden for which this NNA is applicable.

(A-dev)

SE.1.3 Class A

Lines designed for the ice load in accordance with 4.5.2/SE.1.1, SE.1.2, SE.2 and 4.6.4./SE.1.1 and fulfilling the fault current capacity requirements of 11.14/SE.1. Examples are reinforced lines and other lines which are intended to be a part of systems which are used for transmission and distribution over the entire country, or which otherwise are of substantial importance.

(Regulations and general advice of the National Electrical Safety Board regarding the installation of electrical installations ”Elsäkerhetsverkets föreskrifter och allmänna råd om hur starkströmsanläggningar ska vara utförda”, 5 kap. 5 § together with 6 kap. 1, 10 and11 §§, ELSÄK-FS 2022:1).

(ncpt)

SE.1.4 Class B

Lines designed for the ice load in accordance with 4.5.2/SE.1.3, SE.1.4, SE.2 and 4.6.4./SE.1.2. Examples are distribution lines.

Deviation from this classification can be justifiable in special cases. However, the requirements for class B are the minimum requirements for all lines.

(A-dev)

SE.2.1 Reinforced lines type 1

Reinforced lines of type 1 shall fulfil the requirements of class A. Reinforced line of type 1 is demarcated by terminal supports. For lines on timber poles with highest system voltage equal to or less than 55 kV the terminal supports for a reinforced line type 1 can be replaced by demarcation spans. The demarcation spans itself are not considered as a reinforced line.

The route and design of reinforced lines of type 1 shall be such that the risk of damage is prevented as far as possible. Reinforced line of type 1 may thus not be routed over or in perilous vicinity of shooting ranges, chemical industries which emit gas that is harmful to line materials, or locations where combustible objects or inflammables exist to such an extent that a fire could be perilous for the line. Nor may a reinforced line of type 1 or demarcation spans be routed close to buildings or structures of such low structural strength that will not withstand occurring wind loads. It shall be guaranteed that falling trees will not damage the line of type 1 or the demarcation span. (Brottsäker ledning: 6 kap. 1, 10 and 11 §§, ELSÄK-FS 2022:1).

(A-dev)

SE.2.2 Reinforced lines type 2

Reinforced lines of type 2 shall fulfil the requirements of class A. Lines with highest system voltage up to and including 25 kV and routed over urban areas. Reinforced line of type 2 need not to be demarcated by terminal poles or demarcation spans. However, the requirements for reinforced line of type 2 shall also be applied for minimum one span outside the border of the urban area for reinforced lines of type 2 routed in forest. Lines routed in forests shall have a minimum clearance between tree trunk and phase of 3,5 m. Exceptions for a few stray trees down to a clearance distance to 2 m may occur if an investigation state a healthy tree with a solid root system. Remaining vegetation and twigs from trees shall for worst case have a clearance of minimum 1 m (Ledning i förstärkt utförande: 5 kap. 5 § and 6 kap. 1, and 11 §§, ELSÄK-FS 2022:1).

3.6 Design values

3.6.2 Design values of an action

(ncpt)

SE.1

When calculating the effect of the action on the conductor tension, the partial factors γ_F shall be applied to the difference in actual conductor tension and tension at 0 °C in bare conductor. The partial factors γ_F shall not be applied to wind and ice loads for calculation of the conductor tension.

3.7 Partial factor method and design formula

3.7.3.2 Design situations related to permanent and variable actions

(ncpt)

SE.1

For all load cases and load combinations the basic design equation is:

$$E_d = \Sigma\ \gamma_G\ G_K + \Sigma\ \gamma_Q\ Q_{nK}$$

3.7.3.3 Design situations related to permanent, variable and accidental actions

(ncpt)

SE.1

For all load cases and load combinations the basic design equation is:

$$E_d = \Sigma\ \gamma_G\ G_K + \Sigma\ \gamma_Q\ Q_{nK}$$

4 Actions on lines

4.1 Introduction

The Swedish approach for calculation of climatic loads on transmission lines can be classified as an approach 3 method. The value of the peak wind pressure is given directly.

4.3 Wind loads

4.3.4 Turbulence intensity and peak wind pressure

(snc)

SE.1

The characteristic wind pressure $q_p\,(h)$ depends on the height h and the gust wind speed. Height h is the vertical distance in metres from the ground or water surface to the centre of gravity of the wind exposed surface. For a transmission line, which crosses over a single height on a plain or flat country, h is the height to the centre of gravity over the plain.

Values given below are valid for Sweden in general. In mountainous regions and at exposed locations along the coast line higher wind pressures may occur, which have to be considered.

(snc)

SE.1.1 For normal wind conditions the following formulas are valid

for $h \leq 25$ m	$q_p\,(h) = 500$	(N/m^2)
for $h > 25$ m	$q_p\,(h) = 500 + 6 \cdot (h - 25)$	(N/m^2)

(snc)

SE.1.2 For extreme wind conditions the following formulas are valid

for $h \leq 10$ m	$q_p\,(h) = 800$	(N/m^2)
for $h > 10$ m	$q_p\,(h) = 800 + 6 \cdot (h - 10)$	(N/m^2)

NOTE For determining electrical clearances the formulas for normal wind conditions shall be used.

4.4 Wind forces on overhead line components

4.4.1 Wind forces on conductors

4.4.1.1 General

(ncpt)

SE.1

The recommended method for calculating the reference height of the conductor is proposal 1 from Table 4.3, but any of the other proposals can be selected to simplify the calculations.

For the calculation of the mechanical conductor tension in a line-section, a reference height of 25 m can be assumed if no other value may be considered more appropriate.

For covered and insulated conductors, the diameter of the conductor (d) is to be taken as the overall diameter including the thickness of insulation.

4.4.1.2 Structural factor

(ncpt)

SE.1

The structural factor for the conductor is:

for spans $G_C = 0,5$

for jumpers $G_C = 1,0$

4.4.1.3 Drag factor

(ncpt)

SE.1

Method 1 is recommended.

4.4.2 Wind forces on insulator sets

(ncpt)

SE.1

The structural factor, the drag factor and the area of the insulator can be simplified to

$$G_{ins} \cdot C_{ins} \cdot A_{ins} = 0,16 \cdot L_{ins} \quad (m^2)$$

where

L_{ins} is the length of one insulator string (m).

The formula for wind forces on insulator sets can therefore be written

$$Q_{Wins} = q_p\,(h) \cdot 0,16 \cdot L_{ins}$$

4.4.3 Wind forces on lattice towers

4.4.3.1 General

(ncpt)

SE.1

The wind forces on a tower can be determined with method 1 or with method 2.

Reference height of each tower section or each tower member is the height above ground of the geometrical centre of the tower section or the tower member being considered.

4.4.3.2 Method 1

(ncpt)

SE.1

The structural resonance factor is $G_t = G_{tc} = 1,0$

(ncpt)

SE.2 For lattice support the drag factor is:

rectangular cross section with flat sided members	$C_t = 3,95 - 5,79 \cdot \chi + 3,86 \cdot \chi^2$
rectangular cross section with cylindrical members	$C_t = 2,30 - 3,24 \cdot \chi + 2,94 \cdot \chi^2$
triangular cross section with flat sided members	$C_t = 3,40 - 4,71 \cdot \chi + 3,37 \cdot \chi^2$
triangular cross section with cylindrical members	$C_t = 1,95 - 2,68 \cdot \chi + 2,76 \cdot \chi^2$

where χ is the solidity ratio, see Figure 4.2.

(ncpt)

SE.3 For tower body or portal leg with triangular cross section the wind load is:

$$Q_{Wt} = q_p\,(h) \cdot G_t \cdot A_t \cdot C_t \qquad \text{(N/m)}$$

4.4.3.3 Method 2

(ncpt)

SE.1

The structural resonance factor is $G_m = 1{,}0$

The drag factor is $C_m = 1{,}6$ for flat-sided members and 1,0 for cylindrical members.

4.4.4 Wind forces on poles

(ncpt)

SE.1

Method 1 is preferred.

The structural resonance factor is $G_{pol} = 1{,}0$

4.5 Ice load

4.5.2 Ice forces on conductors

(snc)

SE.1 Uniform ice load

For transmission lines in regions where greater uniform ice load is expected, higher values than those given below have to be considered.

(snc)

SE.1.1 Ice load at normal wind conditions for class A lines

Ice load at normal wind conditions $g_{iw} = \pi\, 2{,}916 + \pi\, 0{,}162\, d$ (N/m)

where

d = bare conductor diameter (mm).

For covered and insulated conductors, the diameter of the conductor (d) is to be taken as the overall diameter including the thickness of insulation.

Ice load g_{iw} shall be used in the load cases of normal wind referred to in 4.12.2/SE.

(snc)

SE.1.2 Ice load at no wind for class A lines

$$g_{i0} = \sqrt{(g_{iw} + g_e \cdot 9{,}81)^2 + g_{wi}^2} - g_e \cdot 9{,}81 \qquad \text{(N/m)}$$

where

g_{iw} = ice load at normal wind, N/m

g_e = dead weight of the conductor, kg/m

g_{wi} = normal wind load at conductor covered by ice load, N/m

g_{i0} = ice load at no wind, minimum 20 N/m

Ice load g_{i0} shall be used in the load cases at still air referred to in 4.12.2/SE.

(snc)

SE.1.3 Ice load at normal wind conditions for class B lines

Ice load at normal wind conditions $g_{iw} = \pi\, 0{,}441 + \pi\, 0{,}063\, d$ (N/m)

where

d = bare conductor diameter (mm).

For covered and insulated conductors, the diameter of the conductor (d) is to be taken as the overall diameter including the thickness of insulation.

Ice load g_{iw} shall be used in the load cases of normal wind referred to in 4.12.2/SE.

(snc)

SE.1.4 Ice load at no wind for class B lines

$$g_{i0} = \sqrt{(g_{iw} + g_e \cdot 9{,}81)^2 + g_{wi}^2} - g_e \cdot 9{,}81 \qquad \text{(N/m)}$$

where

g_{iw} = ice load at normal wind, N/m

g_e = dead weight of the conductor, kg/m

g_{wi} = normal wind load at conductor covered by ice load, N/m

g_{i0} = ice load at no wind

Ice load g_{i0} shall be used in the load cases at still air referred to in 4.12.2/SE.

(snc)

SE.1.5 Ice load at normal wind conditions for overhead insulated cables

Ice load at normal wind conditions g_{iw} = 20 N/m

Ice load g_{iw} shall be used in the load cases of normal wind referred to in 4.12.2/SE.

(snc)

SE.1.6 Ice load at no wind for overhead insulated cables

Uniform ice load at no wind g_{i0} = 20 N/m

Ice load g_{i0} shall be used in the load cases at still air referred to in 4.12.2/SE.

(snc)

SE.2 Non uniform ice load

Non-uniform ice load is supposed to appear in any single span while the adjacent spans have no ice. Still air can be assumed during non-uniform ice load.

Non-uniform ice load is expected to be 10 Newton per metre conductor in Sweden in general. For transmission lines in regions where greater non-uniform ice load is expected, higher values have to be considered.

Higher non-uniform ice loads than 10 Newton per metre conductor can be expected within the following regions:

a) Within a zone of some tenths of km width, in open terrain towards the sea along the coast between the cities of Gävle and Haparanda. In such terrain transmission lines of class A and span with crossings in transmission lines of class B shall be designed for a non-uniform ice load of minimum 20 Newton per metre conductor.

b) North of the river Dalälven, in upland terrain approximately 400 m above sea level and higher. In such terrain transmission lines of class A and span with crossings in transmission lines of class B shall be designed for a non-uniform ice load of minimum 30 Newton per metre conductor.

c) Bare mountain regions at altitude above forest. In such terrain the non-uniform ice load can considerably exceed the values given under a) and b). Due to lack of experience no values can be pre-set, and such value shall be determined for each individual case.

4.6 Combined wind and ice loads

4.6.2 Drag factors and ice densities

(snc)

SE.1

The ice density is: ρ_I = 9000 N/m^3 = 917,4 kg/m^3

(snc)

SE.2

The drag factor for ice covered conductors (including insulated cables) is: C_{Ic} = 1,0

4.6.3 Mean wind pressure and peak wind pressure

(snc)

SE.1

The wind at ice condition is the normal wind conditions given in 4.3.4/SE.1.1

4.6.4 Equivalent diameter D of ice covered conductor

(snc)

SE.1 Ice thickness at normal wind condition

(snc)

SE.1.1 Ice thickness at normal wind condition for class A

Ice thickness at normal wind condition	18 mm

For determining the wind surface for ice coated conductors the diameter increased by twice the ice thickness shall be used for the surface calculation.

For covered conductors the diameter of the conductor (d) is to be taken as the overall diameter including the thickness of insulation.

(snc)

SE.1.2 Ice thickness at normal wind condition for class B

Ice thickness at normal wind condition	7 mm

For determining the wind surface for ice coated conductors the diameter increased by twice the ice thickness shall be used for the surface calculation.

For covered conductors the diameter of the conductor (d) is to be taken as the overall diameter including the thickness of insulation.

(snc)

SE.1.3 Ice thickness at normal wind condition for overhead insulated cables

Ice thickness at normal wind condition	10 mm

For determining the wind surface for ice coated conductors the diameter increased by twice the ice thickness shall be used for the surface calculation.

For insulated cables the diameter of the conductor (d) is to be taken as the overall diameter including the thickness of insulation.

4.7 Temperature effects

(snc)

SE.1

The design temperature in all load-cases given in 4.12.2/SE shall be 0 °C unless otherwise noted.

Temperatures for calculation of clearances, see 5.6/SE.2.

4.8 Security loads

(ncpt)

SE.1

Two methods to determine the security load are available: "basic assumption" and "alternative assumption". The most favourable method can be chosen.

(ncpt)

SE.1.1 Basic assumption

For a fixed attached conductor or shield wire, i.e. tension insulator set, pin or line post insulator or shield wire attachment, a reduction factor equal to 0,4 shall be applied to the horizontal component of the conductor force on one side of the support, at uniform ice, conductor temperature 0 °C, in still air at initial stage before conductor creep. For a not fixed attached conductor, i.e. suspension insulator set, a reduction factor equal to 0,7 shall be applied to the horizontal component of the conductor force on one side of the support. No contributing support from the other conductors shall be considered. The vertical component of the conductor force (weight span) shall not be reduced.

(ncpt)

SE.1.2 Alternative assumption

100 % conductor tension reduction for the conductor or shield wire, located at the most unfavourable position, at no ice, conductor temperature 0 °C, in still air at initial stage before conductor creep. When establishing the residual static load it may be assumed, except in crossings, that the adjacent spans are equal to the ruling span of the transmission line. No partial factors apply when establishing the residual static load.

After that the residual static load has been established it shall be increased by applying a partial factor in accordance with Table 4.7/SE.1 or Table 4.7/SE.2 as appropriate.

Relaxation of load resulting from any swing of the insulator assemblies, deflection or rotation of the support and the interaction with other conductors may be made. For bundle conductors, the reduction will affect all sub conductors in the bundle. The weight span shall not be reduced.

4.9 Safety loads

4.9.1 Construction and maintenance loads

(ncpt)

SE.1

All supports shall have the strength and be assembled in such a way that no permanent deformation occurs during construction and maintenance.

4.12 Load cases

4.12.2 Standard load cases

(ncpt)

SE.1

Load cases according to SE.2 and SE.3 are valid for lines with bare and covered conductors.

Load cases according to SE.4 are valid for demarcation spans.

Load cases according to SE.5 are valid for lines with overhead insulated cables.

The design temperature for the following load cases shall be in accordance with 4.7/SE.1.

The tension load in the conductors for the following load cases shall be calculated in accordance with 9.6.4/SE.1 with partial factors according to Table 4.7/SE.1 and 4.7/SE.2. See also 3.6.2/SE.1.

(ncpt)

SE.2 Tangent and angle supports

(ncpt)

SE.2.1 Load case 1a Wind load

This load case shall be used for all types of lines with bare and covered conductors except lines with supports of natural grown timber poles.

- Dead weight
- Wind load on the conductors and on the support with accessories in accordance with 4.3.4/SE.1.2.

(ncpt)

SE.2.2 Load case 2a Uniform ice loads on all spans

- Dead weight
- Uniform ice load at no wind on the conductors in accordance with 4.5.2/SE.1.2 or SE.1.4.
- An additional vertical load Q_k of 1000 N, equivalent to the weight of a linesman with tools, acting in the most unfavourable point. The load is not required for pin insulator hooks and structural parts, which cannot be climbed.

Ice loads on supports can in general be neglected.

(ncpt)

SE.2.3 Load case 2b Uniform ice loads, transversal bending

This load case can normally be ignored in Sweden.

(ncpt)

SE.2.4 Load case 2c - 2d Unbalanced ice loads

These load cases can normally be ignored in Sweden.

(ncpt)

SE.2.5 Load case 3 Combined wind and ice load

- Dead weight
- Ice load at normal wind on the conductors in accordance with 4.5.2/SE.1.1 or SE.1.3.
- Normal wind load on the conductors and on the support with accessories in accordance with 4.3.4/SE.1.1.

Ice loads on supports can in general be neglected.

(ncpt)

SE.2.6 Load case 4 Minimum temperature with/without wind loads

These load cases can normally be ignored in Sweden for lines with bare and covered conductors.

(ncpt)

SE.2.7 Load case 5a Security loads, torsional loads

Natural grown timber poles with accessories and transmission line class B supports do not have to be designed for this load case.

Suspension insulator sets and line-post insulators do not have to be designed for this load case.

(ncpt)

SE.2.7.1 Basic assumption

- Dead weight
- Uniform ice load at no wind on the conductors in accordance with 4.5.2/SE.1.2.
- Reduction of the conductor tension on one side of the support in accordance with 4.8/SE.1.1, Basic assumption. The reduction of the conductor tension is assumed to occur in one conductor only, regardless of the number of circuits per support or the number of conductors per phase.

In this load case crossarms and insulator attachments may be permanently deformed. Clearances shall be maintained to keep the transmission line in provisional service.

Ice loads on supports can in general be neglected.

(ncpt)

SE.2.7.2 Alternative assumption

- Dead weight
- Reduction of the conductor tension on one side of the support in one conductor (one bundle) in accordance with 4.8/SE.1.2, Alternative assumption

(ncpt)

SE.2.8 Load case 5b Security loads, longitudinal loads

This load case can normally be ignored in Sweden except for demarcation spans.

(ncpt)

SE.2.9 Load case 6a Safety loads, construction and maintenance loads

4.9 to be fulfilled.

(ncpt)

SE.2.10 Load case 6b Safety loads, loads due to the weight of linesmen

See SE.2.2

(ncpt)

SE.3 Terminal support

(ncpt)

SE.3.1 Load case 1a Wind load

This load case shall be used for all types of lines with bare and covered conductors except lines with supports of natural grown timber poles.

- Dead weight
- Wind load on the conductors and on the support with accessories in accordance with 4.3.4/SE.1.2.
- Conductor tensions from all conductors or conductor tensions from the conductors on one side of the support, whichever resulting in the most severe stress.

(ncpt)

SE.3.2 Load case 2a Uniform ice loads on all spans

- Dead weight
- Uniform ice load at no wind on the conductors in accordance with 4.5.2/SE.1.2 or SE.1.4.
- Conductor tension from all conductors on one side of the support. Terminal support that demarcates reinforced transmission line shall, in this load case, be designed for the one-sided conductor tensions from all the conductors in the reinforced transmission line. Terminal support that terminates a transmission line at a substation shall be designed for the one-sided conductor tensions from all conductors in the terminated transmission line. It is also recommended to design the terminal support for the one-sided conductor tensions from the conductors between the terminal support and the substation.
- An additional vertical load Q_k of 1000 N, equivalent to the weight of a linesman with tools, acting in the most unfavourable point. The load is not required for pin insulator hooks and structural parts that cannot be climbed.

(ncpt)

SE.3.3 Load case 2b Uniform ice loads, transversal bending

This load case can normally be ignored in Sweden.

(ncpt)

SE.3.4 Load case 2c - 2d Unbalanced ice loads

These load cases can normally be ignored in Sweden.

(ncpt)

SE.3.5 Load case 3 Combined wind and ice load

- Dead weight
- Ice load at normal wind on the conductors in accordance with 4.5.2/SE.1.1 or SE.1.3.
- Normal wind load on the conductors and on the support with accessories in accordance with 4.3.4/SE.1.1.
- Conductor tensions from all conductors or conductor tensions from the conductors on one side of the support, whichever resulting in the most severe stress.

(ncpt)

SE.3.6 Load case 4 Minimum temperature with/without wind loads

These load cases can normally be ignored in Sweden for lines with bare and covered conductors.

(ncpt)

SE.3.7 Load case 5a Security loads, torsional loads

- Dead weight
- Uniform ice load at no wind on the conductors in accordance with 4.5.2/SE.1.2 or SE. 1.4.
- Conductor tension from all conductors, however for some conductors the tension shall be reduced as follows:
- For transmission line class A the reduction of the conductor tension shall be the number and combinations of conductors which results in the most unfavourable case. Reduction in conductor tension in accordance with 4.8/SE.1.1, Basic assumption.
- For transmission line class B reduction of the conductor tension in one conductor in accordance with 4.8/SE.1.1, Basic assumption.

(ncpt)

SE.3.8 Load case 5b Security loads, longitudinal loads

This load case can normally be ignored in Sweden except for demarcation spans.

(ncpt)

SE.3.9 Load case 6a Safety loads, construction and maintenance loads

4.9 to be fulfilled.

SE.3.10 Load case 6b Safety loads, loads due to the weight of linesmen

See SE.3.2

(ncpt)

SE.4 Demarcation support of timber poles

(ncpt)

SE.4.1 Load case 1a Wind load

This load case can normally be ignored for lines with natural grown timber poles in Sweden.

(ncpt)

SE.4.2 Load case 2a Uniform ice loads on all spans

- Dead weight
- Uniform ice load at no wind on the conductors in accordance with 4.5.2/SE.1.2.
- An additional vertical load *Qk* of 1000 N, equivalent to the weight of a linesman with tools, acting in the most unfavourable point. The load is not required for structural parts that cannot be climbed.

(ncpt)
SE.4.3 Load case 2b Uniform ice loads, transversal bending

This load case can normally be ignored in Sweden.

(ncpt)
SE.4.4 Load case 2c - 2d Unbalanced ice loads

These load cases can normally be ignored in Sweden.

(ncpt)
SE.4.5 Load case 3 Combined wind and ice load

- Dead weight
- Ice load at normal wind on the conductors in accordance with 4.5.2/SE.1.1.
- Normal wind load on the conductors and on the support with accessories in accordance with 4.3.4/SE.1.1.

(ncpt)
SE.4.6 Load case 4 Minimum temperature with/without wind loads

This load case can normally be ignored in Sweden for lines with bare and covered conductors.

(ncpt)
SE.4.7 Load case 5a Security loads, torsional loads

This load case can normally be ignored for demarcation spans.

(ncpt)
SE.4.8 Load case 5b Security loads, longitudinal loads

- Dead weight
- Full reduction of the conductor tension on one side of the support in all conductors at 0 °C in initial conditions. The deflection of the support can be considered.

In this load case crossarms and insulator attachments may be permanently deformed. Special strength requirements for timber poles in this load case are stated in 7.5.5.3/SE.1. The clearances shall be maintained to keep the transmission line in provisional service. The ground clearance is equal to the requirements at short circuit condition in accordance with 5.9.2/SE.1 and SE.2.

(ncpt)
SE.4.9 Load case 6a Safety loads, construction and maintenance loads

4.9 to be fulfilled.

(ncpt)
SE.4.10 Load case 6b Safety loads, loads due to the weight of linesmen

See SE.4.2.

(ncpt)
SE.5 Overhead insulated cable lines

(ncpt)
SE.5.1 Load case 1a Wind load

This load case can normally be ignored for lines with overhead insulated cables in Sweden.

(ncpt)
SE.5.2 Load case 2a - 2d Ice load at no wind

These load cases can normally be ignored for lines with overhead insulated cables in Sweden.

(ncpt)
SE.5.3 Load case 3 Combined wind and ice load

- Dead weight

- Ice load at normal wind on the conductors in accordance with 4.5.2/SE.1.5.
- Normal wind load on the conductors in accordance with 4.3.4/SE.1.1.

(ncpt)
SE.5.4 Load case 4 Minimum temperature without wind loads

This load case can normally be ignored for supports.

- Dead weight of conductor
- Minimum temperature in accordance with 5.6/SE.2.1

(ncpt)
SE.5.5 Load case 5a, 5b Security loads

This load case can normally be ignored for lines with overhead insulated cables in Sweden.

(ncpt)
SE.5.6 Load case 6a Safety loads, construction and maintenance loads

4.9 to be fulfilled.

(ncpt)
SE.5.7 Load case 6b Safety loads, loads due to the weight of linesmen

- Dead weight
- An additional vertical load *Qk* of 1000 N, equivalent to the weight of a linesman with tools, acting in the most unfavourable point. The load is not required for structural parts that cannot be climbed.

4.13 Partial factors for actions

(ncpt)
SE.1

The loads which are referred to in the load cases are characteristic load values and shall be multiplied with the partial factors γ_G and γ_Q. Each load case is divided in two load combinations in accordance with Table 4.7/SE.1.

(ncpt) Table 4.7/SE.1 - Partial factors for actions

Action	**Partial factors Symbol**	**Load combination**	
		1[1)]	**2[2)]**
Permanent actions:			
Dead weight of insulators, supports, foundations, soil and ground water	γ_G	1,0	1,0
Dead weight of conductors	γ_G	1,1	1,0
Conductor tension for bare conductors at 0 °C	γ_G	1,1	1,0
Variable actions: Wind and ice loads. Additional loads. Residual static load at one-sided conductor tension reduction, alternative assumption according to 4.8/SE.1.2 Difference in actual conductor tension and tension at 0 °C on bare conductor.	γ_Q	1,43	1,0
Dynamic maintenance and construction loads: e.g. stringing loads or dynamic loads during transportation	γ_G	1,8	1,3

1) Load combination 1 is normally determinant for supports and guys.
2) Load combination 2 is valid for conductors, earth-wires and insulators. Load combination 2 is also valid when checking deformations, electrical clearances and concrete cracks (Serviceability limit state).

(ncpt)

SE.2 Partial factors for actions at guy failure

Partial factors shall be taken from Table 4.7/SE.2 with reference to Table 5.8/SE.5. The most unfavourable load combination shall be used.

(ncpt) Table 4.7/SE.2 - Partial factors for actions at guy failure

Action	**Partial factors Symbol**	**Load combination**
		1
Permanent actions:		
Dead weight of conductors	γ_G	1,1
Dead weight of insulators, supports, foundations, soil and ground water	γ_G	1,0
Conductor tension for bare conductors at +15 °C[1)]	γ_G	1,1
Variable actions: Wind load. Difference at +15 °C between conductor tension at normal wind and no wind.[1)]	γ_Q	1,43

1) At final stadium after the conductor has been subject to ice load and after conductor creep.

5 Electrical requirements

5.3 Insulation co-ordination

(ncpt)

SE.1 Creepage distance of insulator set

Creepage distances for insulators in polluted areas are chosen according to IEC/TS 60815.

Table 5.16/SE.1 gives the creepage distance for vertically positioned phase glass and porcelain insulator sets at different contamination levels. The figures in the Table 5.16/SE.1 are valid for all operation voltage levels and types of system earthing.

For V-sets consisting of string insulator units the figures in Table 5.16/SE.1 may be decreased with 10-20 %. For a horizontally positioned insulator set the washing effect from rain is of great importance. If a good, natural washing effect cannot be expected the creepage distance shall be in accordance with Table 5.16/SE.1.

When very long creepage distance is required the length of the insulator string in certain cases will be larger than normal. In these cases, special arcing devises or electrodes shall be installed in order to reduce the maximum short front overvoltage on a section in the vicinity of a substation.

(ncpt) Table 5.16/SE.1 - Creepage distance for glass and porcelain insulators in contamination areas

Pollution classes	Examples of typical environments	Creepage distance in mm/kV (Phase to earth voltage $U_s/\sqrt{3}$)
Very light	> 50 km from any sea or open dry land > 10 km from man-made pollution sources	22,0
Light	10-50 km from the sea or open dry land 5-10 km from man-made pollution sources	27,8
Medium	Line within 1 km from an area with polluting industries Line protected by forests within 10-20 km from the west coast (Norwegian border-Falsterbo) Line within ~10 km from the south coast (Falsterbo-the north cape of the island of Öland)	34,7
Heavy	Line in area with polluting industries Line in open agricultural areas within 40 km from the west coast Line in other kinds of terrain within 10 km from the west coast	43,3
Very heavy	Line within 0,5 km from area with very severe polluting industries and line within such area Line of considerable importance for the system within some kilometre from the west coast	53,7

(ncpt)

SE.2 Insulators in interphase insulation

The creepage distance phase-to-phase shall be at least 175 % of the creepage distance chosen for phase-to-earth insulation under the same environmental conditions.

5.4 Classification of voltages and overvoltages

(ncpt)

SE.1 Representative overvoltages

The representative overvoltages in the Swedish systems are maximum overvoltages for temporary overvoltages U_V, fast-front overvoltages U_{SK} and slow-front overvoltages U_{SL} The required values are given in Table 5.17/SE.1 and SE.2

The insulation of the line shall withstand the given voltages without breakdown of the insulation under the conditions from voltage testing in accordance with SS-EN 60060.

(ncpt) Table 5.17/SE.1 - Representative overvoltages for systems with earth fault current below 500 A for $U_S \leq 72{,}5$ kV

Highest system voltage U_S (kV)	**Representative temporary overvoltage U_V** (kV_{rms})	**Representative fast-front overvoltage U_{SK}** (kV_{peak})
12	28	75
24	50	125
36	70	170
52	95 1)	250
72,5	140 2)	325 2)
1) May be used under certain conditions for highest operating voltage ≤ 55 kV 2) This level is recommended for systems with highest operating voltage 84 kV		

(ncpt) Table 5.17/SE.2 - Representative overvoltages for systems with earth fault current above 500 A for $145 \leq U_S \leq 420$ kV

Highest system voltage U_S (kV)	**Representative temporary overvoltage U_V** (kV_{rms})	**Representative slow-front overvoltage U_{SL}** (kV_{peak})	**Representative fast-front overvoltage U_{SK}** (kV_{peak})
145	230	350	550
170	275	425	650
245	360	650	850
420	1)	950	1175
1) The representative temporary overvoltage is not considered for the determination of electrical clearances of a 420 kV line.			

The required voltage withstand can be achieved by insulators, wooden distance and/or air-gaps. Required temporary overvoltage withstand and slow-front voltage withstand shall be obtained by the phase insulators only. Required fast-front overvoltage withstand may be achieved by a combination of phase insulator, guy insulator and wooden distance.

The frequency of lightning failures for overhead lines with highest voltage ≤ 72,5 kV is strongly dependent on the insulation withstand level for fast-front overvoltage; the higher fast-front overvoltage withstands the lower failure frequency. It is therefore possible, by selection of insulation withstand level, to obtain lines with different frequency of lightning failures for the same lightning density.

The withstand values given in Table 5.17/SE.1 and SE.2 are phase-to-earth voltages.

(ncpt)

SE.1.1 Representative temporary overvoltages between two phases

The representative temporary overvoltages between two phases shall be at least 175 % of the representative temporary overvoltages between phase-to-earth.

(ncpt)

SE.1.2 Representative slow-front overvoltages between two phases

The representative slow-front overvoltage between two phases shall be at least 140 % for lines with 145 kV to 245 kV and 150 % for lines with 420 kV highest system voltages of the representative slow-front overvoltage phase-to-earth voltage, regarding the extra stress of the insulation between two phases if the operating voltage in one phase is in opposite to the over-voltage in the other phase.

(ncpt)

SE.1.3 Representative fast-front overvoltages between two phases

The representative fast-front overvoltage between two phases in a line shall be at least 115 % of the representative fast-front overvoltage phase-to-earth voltage, regarding the extra stress of the insulation between two phases if the operating voltage in one phase is in opposite to the over-voltage in the other phase.

(ncpt)

SE.1.4 Representative fast-front overvoltages for combined insulation

The fast-front overvoltage withstands for insulation combined of different types of insulation material (porcelain/glass, wood and air) is lower than the sum of the different lengths of insulation.

Supports and crossarms of wood may be a part of the insulation of the line with regard fast-front overvoltages. The fast-front overvoltage withstand is assumed to be at least 0,1 kV/mm wood distance. This value is valid for both impregnated and not impregnated wood.

When the phase-to-earth insulation consists of a phase insulator combined with a guy insulator the additional withstand voltage for the guy insulator shall be as follows:

- Cap and pin insulator 40 kV
- Composite insulator 0,3 kV/mm length

For a line where the support material gives a significant contribution to the phase-to-earth fast-front overvoltage withstand, the fast front overvoltage withstand between two phases is usually less than 115 % of the phase-to-earth withstand voltage. In such cases the fast front overvoltage withstand between two phases shall determine the withstand voltage of the line.

When the fast-front overvoltage withstand is determined by the phase-to-phase insulation the equivalent impulse withstand voltage phase-to-earth is derived from the phase-to-phase withstand voltage divided by the factor 1,15.

For line post or pin insulators the phase to phase fast-front overvoltage withstand obtained can be assumed to be 80 % of the sum of the insulators overvoltage withstand in the two phases. For line string insulators the phase to phase fast front overvoltage withstand obtained can be assumed to be 70 % of the sum of the insulators overvoltage withstand in the two phases.

For lines or sections of lines with wood poles and in systems with earth fault current above 500 A and with metallic crossarms without earth connections the probability to get a phase-to-phase short-circuit in connection to lightning faults is very high when

- the insulation distance between crossarm and earth along pole and/or guy insulator is longer than $3{,}2 \cdot L_1$ (L_1= Arcing distance of the air-gap (mm)) (See also Table 5.8/SE.5)
- the obtained clearance to structural parts of wood exceeds $1{,}1 \cdot L_1$ in load cases E, F and G.

5.5 Minimum air clearance distances to avoid flashover

Air clearances can be calculated according to 5.5/SE.1–SE.2.2. Shorter air clearances shall be validated by tests fulfilling the requirements of Tables 5.17/SE.1 and SE.2.

(ncpt)

SE.1 Calculation of air clearance distances to avoid flashover

$L_1 = U_v/0{,}33$	$(L_1 > 100)$
$L_1 = (U_{SK}-20)/0{,}47$	$(L_1 > 100)$
$L_1 = U_{SL}/0{,}41$	(1 000 < L1 < 3500) when Us > 145 kV

where

U_v = Temporary overvoltage (kV_{rms})

U_{SK} = Fast-front overvoltage 1,2/50 µs (kV_{peak})

U_{SL} = Slow-front overvoltage 250/2500 µs (kV_{peak})

L_1 = Air clearance distances (mm)

(ncpt)

SE.2 Calculation of air clearances for insulator sets

For insulator sets consisting of ordinary cap and pin insulators, the air-gap, to avoid flashover, is calculated in accordance with the following formulas:

(ncpt)

SE.2.1 Insulator set without arc protection devices

$L_2 = (U_v/0{,}28) + 50$	$(150 < L_2 < 785)$
$L_2 = (U_v/0{,}22) - 150$	$(785 < L_2 < 2500)$
$L_2 = (U_{SK}/0{,}52) - 40$	$(150 < L_2 < 2500)$
$L_2 = U_{SL}/0{,}46$	$(1000 < L_2 < 2500)$ when $U_s > 145$ kV

(ncpt)

SE.2.2 Insulator set with arc protection devices

$L_2 = U_v/0{,}31$	$(150 < L_2 < 625)$
$L_2 = (U_v/0{,}25) - 150$	$(625 < L_2 < 2500)$
$L_2 = (U_{SK}/0{,}52) - 40$	$(150 < L_2 < 2500)$
$L_2 = U_{SL}/0{,}46$	$(1\,000 < L_2 < 2500)$ when $U_s > 145$ kV

where

U_v = Temporary overvoltage (kV_{rms})

U_{SK} = Fast-front overvoltage 1,2/50 µs (kV_{peak})

U_{SL} = Slow-front overvoltage 250/2500 µs (kV_{peak})

L_2 = Arcing distance of the insulator set (mm)

5.6 Load cases for calculation of clearances

(ncpt)

SE.1

The clearances within a support shall be obtained for the following combinations of winds, ice loads and temperatures.

For lines with a highest system voltage up to and including 145 kV the load cases C, D, E and F shall be applied.

Load case E and F refers to conditions during thunderstorms. In load cases A to H the clearances shall meet the requirements regardless of the wind direction.

(ncpt)

SE.1.1 Load case A

- Dead weight
- Ice load at normal wind on the conductor, see 4.5.2/SE.1.1
- Normal wind on the conductor, see 4.3.4/SE.1.1
- Temperature 0 °C
- Initial stage before conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.2 Load case B

- Dead weight
- Ice load at normal wind on the conductor, see 4.5.2/SE.1.1
- Normal wind on the conductor, see 4.3.4/SE.1.1
- Temperature 0 °C
- Final stage after conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.3 Load case C

- Dead weight
- Bare conductor
- Normal wind on the conductor, see 4.3.4/SE.1.1
- Temperature +15 °C
- Final stage after conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.4 Load case D

- Dead weight
- Bare conductor
- Normal wind on the conductor, see 4.3.4/SE.1.1
- Minimum temperature at wind, see 5.6/SE.2.1
- Initial stage before conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.5 Load case E

- Dead weight
- Bare conductor
- 30% of normal wind on the conductor, see 4.3.4/SE.1.1
- Temperature +15 °C
- Initial stage before conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.6 Load case F

- Dead weight
- Bare conductor
- 30% of normal wind on the conductor, see 4.3.4/SE.1.1
- Temperature +15 °C
- Final stage after conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.7 Load case G

- Dead weight
- Bare conductors
- No wind
- Temperature +15 °C
- Final stage after conductor creep, see 9.6.4/SE.1

(ncpt)

SE.1.8 Load case H

- Dead weight
- Bare conductor
- No wind
- Minimum temperature, see 5.6/SE.2.1, Design temperatures
- Initial stage before conductor creep, see 9.6.4/SE.1

(snc)

SE.2 Design temperatures

For the calculation of the clearances the following temperatures shall be used:

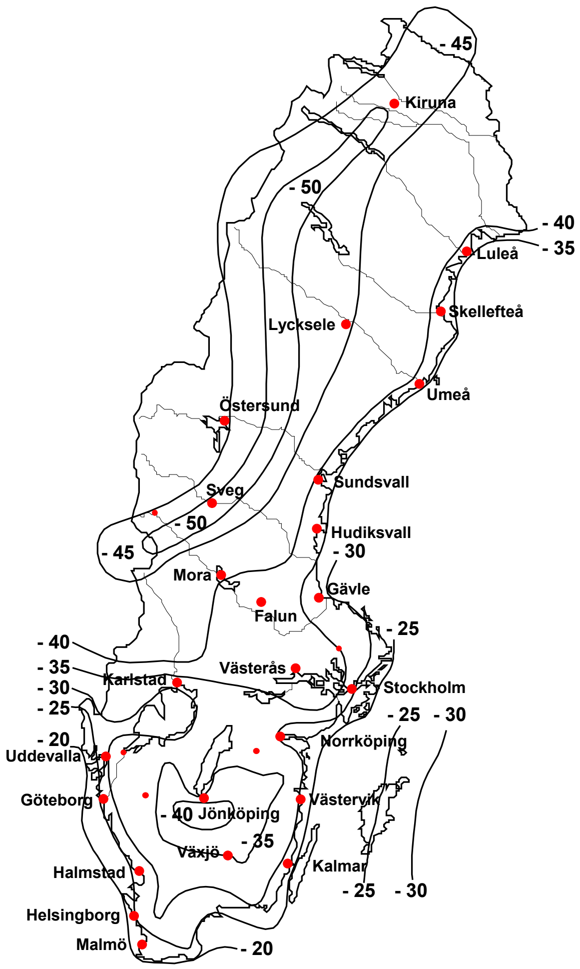
(snc)

SE.2.1 Minimum temperature

a) depending on geographical location from -50 °C up to -25 °C in still air, see Figure 5.6/SE.2.1.

b) at wind conditions 20 °C higher than those stated in *a)*.

c) for overhead insulated cables the minimum temperature is supposed to be –40°C in still air.



(snc) Figure 5.2/SE — Map over Sweden with isotherms for minimum temperature

(snc)

SE.2.2 Maximum temperature in conductor

a) at no wind, minimum +50 °C

NOTE Herein has been assumed that the conductor as a result of the air temperature and solar radiation is heated to +35 °C and the simultaneous rise in temperature by the electrical current effects do not significantly exceed +15 °C. During winter, when air temperature and solar radiation is lower than in summer, a higher current can be allowed provided that the maximum line temperature limit is not exceeded.

b) at normal wind +15 °C

c) for overhead insulated cables the maximum temperature is supposed to be +65 °C in still air or a higher temperature if the manufacturer allows that.

(snc)

SE.2.3 Temperature at ice load

Temperature at ice load is 0 °C.

(ncpt)

SE.2.4 Temperature at exceptional conditions

Temperature at exceptional conditions is when the temperature of the conductor is higher than maximum temperature according to SE.2.2.

Exceptional condition is temporarily operation (a few hours per year) due to non normal operation conditions in other parts of the grid. The operation conditions for the overhead lines, during the load case, are such that adequate safety is maintained.

(ncpt)

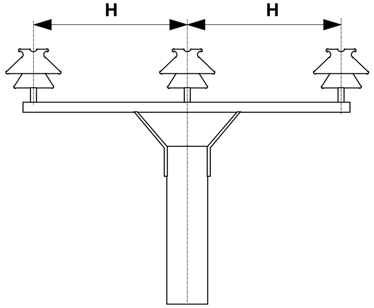
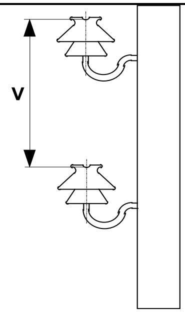
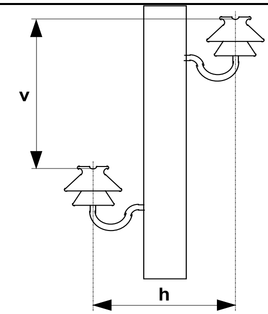
SE.2.5 Temperature at short-circuit conditions

With temperature at short-circuit conditions means the highest temperature that can occur in a conductor during a short circuit if the conductor immediately before the short circuit has its maximum service temperature according to 9.2.3/SE.1 and 9.4/SE.2. The temperature of the conductor during a short circuit depends on the conductor material and area, fault time and the magnitude of the short circuit current.

The maximum temperature for aluminium and aluminium alloyed conductors in overhead insulated cable systems shall not exceed +200 °C. The maximum permitted temperature of the insulation material shall also be taken into consideration. The function of splices, T-off fittings, suspension and tension accessories shall not be affected by this maximum temperature.

5.8 Minimum internal clearances within the span and at the top of support

(ncpt) Table 5.8/SE.1 — Minimum clearances within the span, similar conductors

Clearance within the span		
Similar conductors		
Horizontal configuration of conductors, minimum required mean value of the horizontal distances between the conductor attachment points in the two supports supporting the span	Vertical configuration of conductors, minimum required mean value of the vertical distances between the conductor attachment points in the two supports supporting the span.	Mixed configuration of conductors
$H = 0{,}45\sqrt{b+L} + k \cdot U_s$	$V = k_v \cdot (b_1 - b_2) + L_1 - L_2 + k \cdot U_s$	$h = H\sqrt{1-\frac{v}{V}}$ $v = V(1-\frac{h^2}{H^2})$
		

- b = sag of the conductor, at uniform ice load at no wind and at final stage after conductor creep, (m)
- b_1 = sag of the upper conductor, at uniform ice load at no wind and at initial stage before conductor creep, (m)
- b_2 = sag of the lower conductor, bare conductor at 0 °C and at initial stage before conductor creep, (m)
- L = length of suspension insulator set including any extension link or the distance between the conductor to the attachment point of the suspension clamp in the yoke in case of V-string insulator set (m). (L=0 for tension insulator set and line post insulators)
- L_1 = length of suspension insulator set for the upper conductor
- L_2 = length of suspension insulator set for the lower conductor
- k = coefficient which is 0,007 for phase-to-phase calculation and 0,006 for phase-to-earth calculation.

Type of conductor	**Coefficient k_v**	
	Tension set and pin or post insulator	**Suspension set and V-set**
ACSR, AAC or AAAC	1,0	1,1
Copper and steel	1,2	1,3

The formula for H is only valid for suspension sets if the relationship a_h/a_v for both conductors are equal in each of the adjacent supports, where ah is the wind span and av the weight span

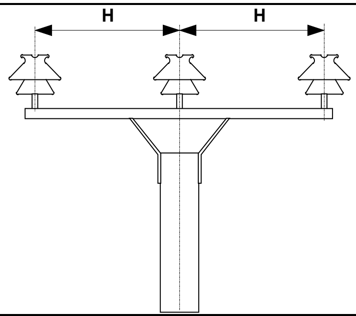
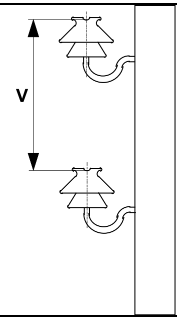
NOTE 1 The given formulas shall be used for normal conditions. Special investigation shall be made for conductors with low tension, where galloping may occur or where the conductor configuration is different in the two supports, which demarcate the span.

NOTE 2 The attachment point for conductor is: Top of the insulator for pin or post insulators, attachment point in the support for suspension or tension insulator sets, attachment point in the yoke plate of the suspension clamp for V-string insulator sets.

NOTE 3 For covered conductors the clearance within the span shall be at least 1/3 of the clearance calculated according to Table 5.8/SE.1 and SE.2. The clearance shall however be at least 115% of the clearance phase to earth at load case E and F, see Table 5.8/SE.4.

NOTE 4 In addition to the above requirements the distance between the conductor attachment points for Reinforced lines type 2 shall not be less than $0{,}6+0{,}007 \cdot U_s$ (m)

(ncpt) Table 5.8/SE.2 — Minimum clearances within the span, dissimilar conductors

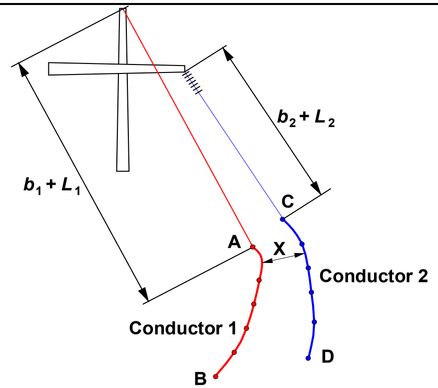
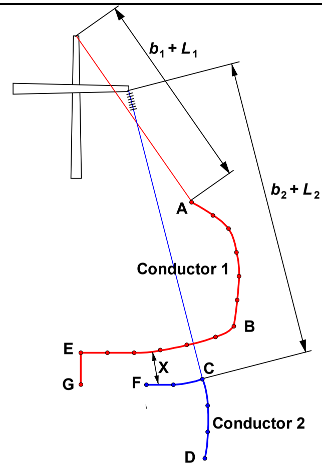
<table>
<tr><th colspan="4">Clearance within the span</th></tr>
<tr><td colspan="4">Dissimilar conductors</td></tr>
<tr><td>Horizontal configuration of conductors
Minimum required mean value of the horizontal distances between the conductor attachment points in the two supports supporting the span</td><td colspan="3">Vertical configuration of conductors
Minimum required mean value of the vertical distances between the conductor attachment points in the two supports supporting the span</td></tr>
<tr><td>$H = (b_1 + L_1)\sin\alpha_1 - (b_2 + L_2)\sin\alpha_2 + k \cdot U_s$
$\alpha_1 = \mathrm{arctg}\dfrac{g_{wi}}{g_e \cdot 9{,}81 + g_{iw}}$ $\alpha_2 = \mathrm{arctg}\dfrac{0{,}7 \cdot g_{wi}}{g_e \cdot 9{,}81 + g_{iw}}$</td><td colspan="3">$V = k_v \cdot (b_1 - b_2) + L_1 - L_2 + k \cdot U_s$</td></tr>
<tr><td>
</td><td colspan="3">
</td></tr>
<tr><td>α = swing-out angle of the conductor, (°)
b = sag of the conductor, at uniform ice load at no wind and at initial stage before or after conductor creep whichever is the most unfavourable, (m)
L = length of the upper suspension insulator set including any extension link or the distance between the conductor to the attachment point of the suspension clamp in the yoke in case of V-string insulator set (m). (L=0 for tension insulator set and line post insulators)
k = coefficient which is 0,007 for phase-to-phase calculation and 0,006 for phase-to-earth calculation.
g_e = dead weight of the conductor (kg/m)
g_{iw} = Ice load at normal wind (N/m)
g_{wi} = normal wind load at conductor covered by ice load (N/m)</td><td colspan="3">b_1 = sag of the upper conductor, uniform ice load at no wind and at initial stage before or at final stage after conductor creep whichever is the most unfavourable (m)
b_2 = sag of the lower conductor, bare conductor at 0 °C and at initial stage before or at final stage after conductor creep whichever is the most unfavourable (m)
L_1 = length of the upper suspension insulator set including any extension link or the distance between the conductor to the attachment point of the suspension clamp in the yoke in case of V-string insulator set (m). (L=0 for tension insulator set and line post insulators)
L_2 = length of the lower suspension insulator set including any extension link or the distance between the conductor to the attachment point of the suspension clamp in the yoke in case of V-string insulator set (m). (L=0 for tension insulator set and line post insulators)
k = coefficient which is 0,007 for phase-to-phase calculation and 0,006 for phase-to-earth calculation.</td></tr>
<tr><td rowspan="4">Conductor 1 is the conductor which is first hit by 100% of the normal wind and conductor 2 is the conductor which is hit and by 70 % of the normal wind.
H shall be calculated for both wind directions

The formula for H is only valid for suspension sets if the relationship a_h/a_v for both conductors are equal in each of the adjacent supports, where a_h is the wind span and a_v the weight span</td><th rowspan="2">Type of conductor</th><th colspan="2">Coefficient k_v</th></tr>
<tr><th>Tension set and pin or post insulator</th><th>Suspension set and V-set</th></tr>
<tr><td>ACSR, AAC or AAAC</td><td>1,0</td><td>1,1</td></tr>
<tr><td>Copper and steel</td><td>1,2</td><td>1,3</td></tr>
<tr><td colspan="4">The formulas shall be used as according to NOTE 1 in table 5.8/SE.1.</td></tr>
</table>

(ncpt) Table 5.8/SE.3 — Minimum clearances within the span, dissimilar conductors

<table>
<tr><td></td><td colspan="2">Clearance within the span</td></tr>
<tr><td></td><td colspan="2">Dissimilar conductors</td></tr>
<tr><td></td><td colspan="2">Mixed configuration of conductors
This method determine the shortest distance X between two curves A-B and C-D in Case 1 or B-E-G and C-F in Case 2. The curves describe the sag and swing of the conductors under influence from dead weight and increasing ice- and wind loads.
The calculation has to be made for the most unfavourable condition of sag before or after creep of the conductor. For equal conductors in the same line only sag before creep shall be considered. The wind is supposed to act in the most unfavourable direction. For span with angle supports the difference between the insulator swing angle and the conductor swing angle shall be considered. For tangent supports the insulator swing angle may be assumed to be equal to the conductor swing angle.
Clearance requirement in accordance with case 2 is applicable when the swing of conductor 1 is greater than that of conductor 2. This is the case when a vertical line through point C is positioned between the attachment point of conductor 1 and point B.</td></tr>
<tr><td>Load Case</td><td>Case 1</td><td>Case 2</td></tr>
<tr><td></td><td>•Conductor 1 - dead weight and with ice load increasing from zero at point A to 100% (g_{iw}) at point B and wind load g_{w0} at point A to g_{wi} at point B.

•Conductor 2 - dead weight and with ice load increasing from zero at point C to 100% (g_{iw}) at point D and wind load 0,7 · g_{w0} at point C to 0,7 · g_{wi} at point D.</td><td>•Conductor 1 - dead weight and with 100% ice load (g_{iw}) at point E and normal wind load increasing from zero at point E to gwi at point B. For no wind condition the ice load is increasing from g_{iw} at point E to g_{i0} at point G. The curve A-B is calculated in accordance with Case 1 above.

•Conductor 2 - dead weight and with normal wind load increasing from zero at point F to 0,7 · g_{w0} at point C. The curve C-D is calculated in accordance with Case 1 above.</td></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td colspan="3">g_{i0} = Ice load at no wind (N/m)
g_{iw} = Ice load at normal wind (N/m)
g_{w0} = normal wind load at bare conductor (N/m)
g_{wi} = normal wind load at conductor covered by ice load (N/m)
b = sag of the conductor (m)
L = length of suspension insulator set (m)
k = coefficient which is 0,007 for phase-to-phase calculation and 0,006 for phase-to-earth calculation
X ≥ k · U_s</td></tr>
</table>

(ncpt) Table 5.8/SE.4 — Minimum clearances within the tower

	Clearance at the tower								
	Minimum air clearance phase to earth (mm)								
	Systems with earth fault current below 500 A					Systems with earth fault current above 500 A			
Load Case	$U_s \leq 12$ kV	$U_s \leq 24$ kV	$U_s \leq 36$ kV	$U_s \leq 52$ kV	$U_s \leq 72,5$ kV	$U_s \leq 145$ kV	$U_s \leq 170$ kV	$U_s \leq 245$ kV	$U_s \leq 420$ kV
Load case A, B, C, D and H, see Subclause 5.6/SE.1.	-	-	-	-	-	600	650	900	1200
Load case C and D, see Subclause 5.6/SE.1.	90	130	190	250[1)]	370	-	-	-	-
Load case E and F, see Subclause 5.6/SE.1.	160	220	320	480	630	1000	1200	1600	2200
Load case G, see Subclause 5.6/SE.1.	-	-	-	-	-	-	1400	1850	2600
Remarks	At load case E and F maximum 40 % of the clearance in air, may be replaced by wooden distance of at least five times the substituted clearance or by an equivalent combined insulation. For determining phase to phase distances, see section 5.4/SE.1 and 5.5/SE.1.								
1) May on special conditions be allowed for highest operating voltage ≤ 55 kV									

(ncpt) Table 5.8/SE.5 — Air clearance to guy wire

	Guys shall be arranged and designed according to Subclause 7.7.6/SE.1				
	Air clearance to guy wire in system with earth fault current above 500 A:				**Air clearance to guy wire in system with earth fault current below 500 A:**
	Support with earthed metallic crossarm or insulator support: Air clearance to guy (mm) according to the table below.		**Support with not earthed metallic crossarm:** Minimum air clearance to guy (mm) according to the table below.		The clearance in accordance with Subclause 5.8/SE.4 shall be fulfilled. If a short-circuit phase-to-phase can cause failure of a guy due to too high temperature, the guy shall be designed in accordance with guys in systems with earth fault current above 500 A.
Load Case	Lower conductive part of stay insulator	Insulated part of stay insulator	Lower conductive part of stay insulator	Insulated part of stay insulator	
Load case E, F and G, see Subclause 5.6/SE.1.5-1.7.	1,5·L	1,1·L	1,8·L	1,1·L	
	If the minimum air clearance to guy (mm) is less than in the table above the guy must be designed to fulfill the requirements specified in Table 5.8/SE.6 – Maximum current density for guy-components. The clearances of Table 5.8/SE.4 shall always be maintained at load cases as specified.		Air clearance less than in table above is not allowed. See also 5.4/SE.1.4.		
Remarks	L = the arcing distance of the insulator set, (mm). Timber poles in systems with earth fault current below 500 A shall: • Maintain clearance from pin type insulator attachment and with such attachment connected conductive structural part to guy wire attachment to be at least 0,2 m. • Be equipped with stay-insulator. The stay-insulator shall be placed at least 2,5 m from the attachment of the conductor and at least 3 m above ground. Stay-insulator is not required for guy which is attached minimum 2 m below the lowest insulator attachment and with such attachment connected conductive structural part, neither if the guy is connected to earth.				

(ncpt) Table 5.8/SE.6 — Maximum current density for guy-components

The maximum allowed current density for guy components shall be in accordance with the table below

Component	Final temperature at short-circuit,˚C	Current density at design tripping time		
		1,0 s A/mm²	0,5 s A/mm²	Guy may be designed only for mechanical loads if the support is designed in such a way that the permissible mechanical stress is not exceeded after a guy failure when the support is subjected to normal wind load, no ice load, conductor temperature +15 °C. All load conditions shall be at final stage after the conductor has been subjected to ice load and after conductor creep. This shall be fulfilled with partial factors according to Table 4.7.2/SE.2.
Guy-wire, Steel	300	58	82	
Guy-wire, ACSR	300	123[1)]	174[1)]	
Accessories of steel	400	70	99	
Accessories of cast iron	400	40[2)]	57[2)]	

1) Only the aluminum portion shall be considered.
2) Higher values may be used if verified with tests.

5.9 External clearances

5.9.1 General

(A-dev)

SE.1 Voltage dependent distance S

S = a voltage dependent distance for lines with a highest system voltage exceeding 55 kV in accordance with the following formulas:

$U_s \leq 55$ kV	S = 0	
$U_s > 55$ kV		
at systems with earth fault current above 500 A	$S = 0{,}005 \cdot (U_s - 55)$	(m)
at systems with earth fault current below 500 A	$S = 0{,}007 \cdot (U_s - 55)$	(m).

(ELSÄK-FS 2022:1, 6 kap., 3 §.)

5.9.2 External clearances to ground in areas remote from buildings, roads, etc.

(A-dev) Table 5.9.2/SE.1 — Minimum clearance in rural areas and not navigable waterways

	Clearance to ground in rural areas and not navigable waterways			**Clearance to trees**			
	Overhead insulated cable system with an earthed intermediate shield	Bare or covered conductor	Earth wire	Under the line (Vertical clearance). Horizontal clearance between part of a tree and nearest phase conductor for $U_s \leq 72,5$ kV Clearance between falling trees and nearest phase in lines for $U_s \geq 145$ kV.			
Load Case				$U_s \leq 72,5$ kV	$U_s \leq 145$ kV	$U_s \leq 245$ kV	$U_s \leq 420$ kV
Maximum conductor temperature at no wind, see Subclause 5.6/SE.2.2	4,5 m	6 m + S	-	-	-	-	-
Uniform ice load at no wind at 0 ºC, see Subclause 4.5.2/SE.1.2 and SE.1.4	-	4,5 m + S	-	-	-	-	-
Non-uniform ice-load at 0 ºC, see Subclause 4.5.2/SE.2	-	4,5 m + S	-	-	-	-	-
Temperature during exceptional conditions, see Subclause 5.6/SE.2.4		4,5 m + S	-	-	-	-	-
Temperature at short-circuit conditions, see Subclause 5.6/SE.2.5	-	4,5 m + S	-	-	-	-	-
All load cases	-	-	4,5 m	1,0 m	1,5 m	2,5 m	3,5 m
Remarks	All load cases means that this clearance comprises all load situations as a minimum clearance allowed according to regulations. Overhead electrical lines with insulated cable system with an earthed intermediate shield may have a reduced vertical clearance to ground in connection with the entrance of the building. Clearance for earth wire is also applicable for ADSS cable			The horizontal clearance to trees in the vicinity of the line depends on whether an earth fault is acceptable or not. Earth fault is acceptable only in lines for $U_s < 145$ kV. Horizontal clearance between covered phase conductor and trunk of tree shall be at least 1,5 m. The clearance to branches and other objects shall be sufficient to avoid wearing-damages on the covered conductor. Horizontal clearance between the nearest phase conductor of reinforced line type 2 and the trunk of a tree shall be at least 3,5 m. Horizontal clearance between phase conductor and the nearest part of a tree (a branch) shall never be less than 1,0 m at the most unfavourable load case.			
NOTE 1 In areas where the snow layers normally exceeds 1 m the minimum clearance shall be increased with 0,5 m for load cases associated with ice.							
NOTE 2 In not navigable waterways clearance to ground corresponds to clearance to mean high-water level.							

(A-dev) Table 5.9.2/SE.2 — Minimum clearance in urban areas

	Clearance to ground in urban areas		
	Overhead insulated cable system with an earthed intermediate shield	Bare or covered conductor	Earth wire
Load Case			
Maximum conductor temperature at no wind, see Subclause 5.6/SE.2.2	-	7 m + S	-
Uniform ice load at no wind at 0 ºC, see Subclause 4.5.2/SE.1.2 and SE.1.4	-	7 m + S	-
Non-uniform ice-load at 0 ºC, see Subclause 4.5.2/SE.2	-	7 m + S	-
Temperature during exceptional conditions, see Subclause 5.6/SE.2.4	-	7 m + S	-
Temperature at short-circuit conditions, see Subclause 5.6/SE.2.5	-	6 m + S	-
All load cases	6 m	-	6 m
Remarks	All load cases means that this clearance comprises all load situations as a minimum clearance allowed according to regulations. Overhead electrical lines with insulated cable system with an earthed intermediate shield may have a reduced vertical clearance to ground in connection with the entrance of the building. Clearance for earth wire is also applicable for ADSS cable. In urban areas the overhead line must be built as reinforced line type 1 or as reinforced line type 2 for lines with nominal voltage not exceeding 25 kV.		

(A-dev) Table 5.9.2/SE.3 — Minimum clearance to area with inflammable goods and to store of explosives

	Horizontal clearance to area with inflammable goods				**Horizontal clearance to store of explosives**	
Load Case	$12 \le U_s \le 72,5$ kV	$72,5 < U_s \le 170$ kV	$170 < U_s \le 245$ kV	$U_s \le 420$ kV	$U_s < 145$ kV	$U_s \ge 145$ kV
Maximum conductor temperature at no wind, see Subclause 5.6/SE.2.2	15 m	30 m	45 m	60 m	50 m	100 m
Remarks	NOTE 1 Power lines shall be routed in adequate safety distance from store of combustible materials. NOTE 2 Clearances given above is a guidance for normally safe distances for areas with inflammable goods and to store of explosives. NOTE 3 For other distances and conditions than mentioned above, and distances from store of combustible materials, the adequate safety distance can be established by risk assessment with respect to the actual conditions.					

5.9.3 External clearances to residential and other buildings

(A-dev) Table 5.9.3/SE.1 — Minimum clearance to residential and other buildings

<table>
<tr><td></td><td colspan="7">Clearance cases: Residential and other buildings</td></tr>
<tr><td></td><td>Line above buildings</td><td colspan="4">Line adjacent to buildings (Horizontal clearance)</td><td>Street lightning, flag poles, fences and similar structures which cannot be stood on</td><td>Antennas, masts, towers for wind power plants etc.</td></tr>
<tr><td></td><td></td><td colspan="2">Rural areas</td><td colspan="2">Urban areas</td><td>Clearance in any direction</td><td>Horizontal clearance</td></tr>
<tr><td>Load Case</td><td></td><td>$U_s \leq$ 55 kV</td><td>$U_s >$ 55 kV</td><td>$U_s \leq$ 55 kV</td><td>$U_s >$ 55 kV</td><td></td><td rowspan="8">Distances shall consider risks due to falling objects/ice, earth potentials and flight inspection safety.

Recommended minimum horizontal clearance is the height of the mast/tower including turbine blade.</td></tr>
<tr><td>Maximum conductor temperature at no wind, see Subclause 5.6/SE.2.2</td><td>-</td><td>5 m</td><td>5 m + S</td><td>5 m</td><td>10 m</td><td>4 m</td></tr>
<tr><td>Uniform ice load at no wind at 0 °C, see Subclause 4.5.2/SE.1.2 and SE.1.4</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>4 m</td></tr>
<tr><td>Non-uniform ice-load at 0 °C, see Subclause 4.5.2/SE.2</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>4 m</td></tr>
<tr><td>Temperature during exceptional conditions, see Subclause 5.6/SE.2.4</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>4 m</td></tr>
<tr><td>Temperature at short-circuit conditions, see Subclause 5.6/SE.2.5</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>2 m</td></tr>
<tr><td>Maximum swing out angle at normal wind and at maximum temperature at wind</td><td>-</td><td>3 m</td><td>3 m + S</td><td>3 m</td><td>3 m + S</td><td>4 m</td></tr>
<tr><td>Maximum swing-out angle of the phase conductor at normal wind and ice load at 0 °C see Subclause 4.5.2/SE.1.1 and SE.1.3</td><td>-</td><td>3 m</td><td>3 m + S</td><td>3 m</td><td>3 m + S</td><td>4 m</td></tr>
<tr><td>Remarks</td><td>1)</td><td colspan="4">Overhead electrical lines with insulated cable system with an earthed intermediate shield may have a reduced vertical clearance to ground in connection with the entrance of the building.</td><td>If risk of collision with vehicles is present, the clearance between the falling street lightning pole and the nearest phase conductor shall be at least 1 m + S.

Overhead transmission line shall cross above the street lightning installation.</td><td></td></tr>
<tr><td colspan="8">1) It is not permitted to cross over buildings with overhead electric lines with conductor or covered conductor design. Exceptions are permitted above minor not electrified buildings such as minor tool sheds or store sheds if safety can be attained. Safety considerations must be taken concerning the size of the building, risk of transferred potentials, distance to phase conductor, the nominal voltage and the design of the overhead line, see Subclause 6.4 and 6.1.4. Clearances from top of the building see Table 5.9.2/SE.1.</td></tr>
</table>

5.9.4 External clearances to crossing traffic routes

(A-dev) Table 5.9.4/SE.1 — Minimum clearance to line crossing roads, railways and navigable waterways

Clearance cases: Line crossing roads and parking lots							
	Public used roads			Other roads			Parking lots
	Overhead insulated cable system with an earthed intermediate shield	Bare or covered conductor	Earth wire	Overhead insulated cable system with an earthed intermediate shield	Bare or covered conductor	Earth wire	Overhead lines in close proximity to a parking lot shall be located in a way that ensures safety. Minimum horizontal clearances according to Table 5.9.3/SE.1 (line adjacent to buildings) fulfil this requirement. Overhead lines in the proximity of the parking lots, where vehicles for inflammable or explosive goods are allowed, shall have clearances according to Table 5.9.2/SE 3.
Load Case							If it is not possible to fulfil the second paragraph above, a deviation can be acceptable if an agreement between the overhead line owner and the owner of the property where the parking lot is established to guarantee the safety conditions in addition with the following requirements: - The parking lot is only intended for private cars and similar vehicles. - The parking lot must be an enclosed area or the access must be height restricted by physical means. - Vehicles used for transport of explosive or inflammable goods are not allowed. - The overhead line must be constructed as a reinforced line over the parking lot. - Actions to prevent collision to poles and guys must be taken. - Repair and maintenance can be made without interference of parked vehicles. - Clearances for public used roads shall be used.
Maximum conductor temperature at no wind, see Subclause 5.6/SE.2.2	-	7 m + S	-	-	6 m + S	-	
Uniform ice load at no wind at 0 °C, see Subclause 4.5.2/SE.1.2 and SE.1.4	-	7 m + S	-	-	6 m + S	-	
Non-uniform ice-load at 0 °C, see Subclause 4.5.2/SE.2	-	7 m + S	-	-	6 m + S	-	
Temperature during exceptional conditions, see Subclause 5.6/SE.2.4		7 m + S			6 m + S	-	
Temperature at short-circuit conditions, see Subclause 5.6/SE.2.5	-	6 m + S	-	-	6 m + S	-	
All load cases	6 m	-	6 m	6 m	-	6 m	
Remarks				Clearance given for crossing with public road shall also be valid for other roads with public traffic and other roads where transportation with high vehicles can take place, e.g. roads with traffics for timber lorries			
	Clearance for earth wire is also applicable for ADSS cable						

NOTE 1 Lines in crossings must be built as reinforced lines type 1 or according to the Swedish Standards for crossings, SS 436 02 61, SS 436 02 62, SS 436 02 63, SS 436 02 65, SS 436 02 66, SS 436 02 80 and SS 436 02 81.

(A-dev) Table 5.9.4/SE.2 — Minimum clearance to line crossing roads, railways and navigable waterways

Clearance cases: Line crossing railways and navigable waterways										
	Not electrified railways			Electrified railway	Navigable waterways (Vertical clearance to mean high-water level) (Clearance prescribed by the authorities)			Navigable waterways (Vertical clearance to mean high-water level) (Clearance not prescribed by the authorities)		
	Overhead insulated cable system with an earthed intermediate shield	Bare or covered conductor	Earth wire	Minimum clearance between the top surface of the rail and the conductor in the overhead line	Clearance with reference to lowest located wire/conductor/cable			Overhead insulated cable system with an earthed intermediate shield	Bare or covered conductor	Earth wire
Load Case					$U_s \leq$ 170 kV	170 kV < U_s ≤ 245 kV	245 kV < U_s ≤ 420 kV			
Maximum conductor temperature at no wind, see Subclause 5.6/SE.2.2	-	8 m + S	-	-	-	-	-	7 m	7 m + S	7 m
Uniform ice load at no wind at 0 ºC, see Subclause 4.5.2/SE.1	-	8 m + S	-	-	-	-	-	-	6 m + S	6 m
Non-uniform ice-load at 0 ºC, see Subclause 4.5.2/SE.2	-	8 m + S	-	-	-	-	-	-	6 m + S	6 m
Temperature during exceptional conditions, see Subclause 5.6/SE.2.4	-	8 m + S	-	-	-	-	-	-	6 m + S	6 m
Temperature at short-circuit conditions, see Subclause 5.6/SE.2.5	-	6 m + S	-	-	-	-	-	-	6 m + S	6 m
All load cases	7 m	-	7 m	-	W + 1,5 m	W + 2,0 m	W + 2,75 m	-	-	-
Remarks				Minimum clearance is decided and specified for each situation by the authority Swedish National Electrical safety Board after consultation of the owner of the railway. A recommended value is 13,5 m for railways with normal use.	W = free space for sailing from normal high-water level given by the authorities.			A duty to report to authorities is mandatory before any erection or construction of the power line take place. Other clearance distances can be prescribed for a specific overhead line by the authorities or through the licence for the overhead line. Additional prescriptions are stated in Swedish law by the ordinance SFS 2017:218.		
	Clearance for earth wire is also applicable for ADSS cable									
NOTE 1 Lines in crossings must be built as reinforced lines type 1 or according to the Swedish Standards for crossings, SS 436 02 61, SS 436 02 62, SS 436 02 63, SS 436 02 65, SS 436 02 66, SS 436 02 80 and SS 436 02 81.										

5.9.6 External clearances to other power lines or overhead telecommunication lines

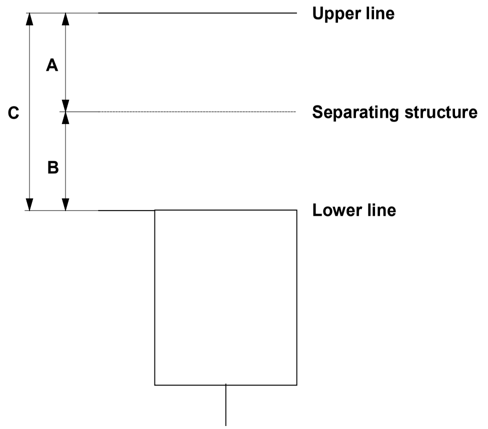
(ncpt) Table 5.9.6/SE.1 — Minimum clearance to other power lines or overhead telecommunication lines

	Crossing without separating structure Minimum vertical clearance (m)		
Load Case	Upper line U_s > 1 kV Lower line $U_s \leq$ 1 kV or telecommunication	Upper line U_s > 1 kV Lower line U_s > 1 kV	Upper line U_s > 1 kV Lower line: Earth wire
I - IV	4 m + S[1)]	2,5 m + S; but at least 4 m[1)]	1,5 m + S
V - VI	2 m + S	0,5 m + S; but at least 2 m	1,5 m + S
	The clearance in the table shall be fulfilled in the most unfavourable of the load cases I-VI: I) Upper line at maximum temperature and at no wind in final condition - Lower line with bare conductor at 0º C and no wind in initial condition II) Upper line at 0º C and at uniform ice load and no wind in final condition - Lower line with bare conductor at 0º C in initial condition III) Upper line at 0º C and at non-uniform ice load in final condition - Lower line with bare conductor at 0º C in initial condition IV) Upper line with bare conductor at 0º C in final condition - Lower line with bare conductor at 0º C in initial condition V) Upper line at short-circuit temperature in final condition - Lower line at maximum temperature and at no wind in final condition VI) Upper line at minimum temperature increased with temperature-rise due to short-circuit current in final condition - Lower line with bare conductor at minimum temperature at no wind in initial condition. 1) For upper line ≤ 55 kV the clearance may be reduced to 2,5 m if the distance from the crossing point to the nearest pole in the two lines is ≤ 15 m.		
	Clearance for earth wire is also applicable for ADSS cable.		

NOTE 1 The temperature-rise is defined as the difference between short-circuit temperature and maximum temperature.

NOTE 2 Lines in crossings must be built as reinforced lines type 1 or according to the Swedish Standards for crossings, SS 436 02 61, SS 436 02 62, SS 436 02 63, SS 436 02 65, SS 436 02 66, SS 436 02 80 and SS 436 02 81.

(ncpt) Table 5.9.6/SE.2 — Minimum clearance to other power lines or overhead telecommunication lines

	Crossing with separating structure Minimum vertical clearance (m)			
Load Case	Upper line U_s > 1 kV Lower line U_s ≤ 1 kV or telecommunication	Upper line U_s ≥ 1 kV Lower line 1 kV < U_s ≤ 170 kV	Upper line U_s ≥ 1 kV Lower line 170 kV < U_s ≤ 245 kV	Upper line U_s ≥ 1 kV Lower line 245 kV < U_s ≤ 420 kV
Distance A	1 m + S	1 m + S	1 m + S	1 m + S
Distance B	1,5 m[1)]	1,5 m[2)]	2 m	3,5 m
Distance C	2,5 m + S[3)]	2,5 m + S	3 m + S	4,5 m + S
Remarks	**The clearance in the table shall be fulfilled in the most unfavourable of the load cases I-VI:** I) Upper line at maximum temperature and at no wind in final condition - Lower line with bare conductor at 0º C and no wind in initial condition II) Upper line at 0º C and at uniform ice load and no wind in final condition - Lower line with bare conductor at 0º C in initial condition III) Upper line at 0º C and at non-uniform ice load in final condition - Lower line with bare conductor at 0º C in initial condition IV) Upper line with bare conductor at 0º C in final condition - Lower line with bare conductor at 0º C in initial condition V) Upper line at short-circuit temperature in final condition - Lower line at maximum temperature and at no wind in final condition VI) Upper line at minimum temperature increased with temperature-rise due to short-circuit current in final condition - Lower line with bare conductor at minimum temperature at no wind in initial condition.  			
	1) If the separating structure is self-supported the distance B, can be reduced to 1 m.			
	2) If the separating structure is self-supported the distance B, can be reduced to 1 m if the voltage of the lower line is less than or equal to 55 kV. If lower line has voltage ≤ 55 kV and earth wire over the phases then the distance between earth wire and separating structure can be reduced to 0,5 m. Distance C, shall be kept in both cases.			
	3) For upper line ≤ 55 kV and if the crossing span is situated close to a demarcation span and if the horizontal distance between the crossing point and the nearest pole of the crossing line is more than 25 % of the length of the crossing span, then the distance C, shall be 3 m.			
NOTE 1	The temperature-rise is defined as the difference between short-circuit temperature and maximum temperature.			
NOTE 2	Lines in crossings must be built as reinforced lines type 1 or according to the Swedish Standards for crossings, SS 436 02 61, SS 436 02 62, SS 436 02 63, SS 436 02 65, SS 436 02 66, SS 436 02 80 and SS 436 02 81.			

(A-dev)* (ncpt) Table 5.9.6/SE.3 — Minimum clearance to other power lines or overhead telecommunication lines

	Parallel lines in the same support Minimum clearance (m)		
	– Parallel lines of separate utilities shall, if possible, be installed in separate supports. *(ELSÄK-FS 2022:1, 6 kap. 2 §). – Parallel lines in the same support shall fulfill requirements of this table. – If parallel lines origin from separate utilities, there shall be a documented agreement between the utility parties with descriptions related to maintenance and other measures related to how electrical safety shall be performed. *(ELSÄK-FS 2022:3, 13 §). – Mix up between the parallel or converging overhead lines shall be prevented by necessary marking. – Overview earthing systems and conductive supports in non-conductive pole, see Table 6.3/SE.5 and 6.4/SE.6.		
	Bare or covered Conductors, U_s > 1 kV	**Cables, U_s > 1 kV**	**Covered Conductors, U_s ≤ 1 kV**
Bare or covered Conductors, U_s > 1 kV	See Subclause 5.8/SE1-SE3 1) Presence of earth/shield wire 3)	1+0.02(L-50) for L > 50 but at least 1 m Specific earthing requirements 3)	– 2) Specific earthing requirements 4)
Cable, U_s > 1 kV	1+0,02(L-50) for L > 50 but at least 1 m Specific earthing requirements 3)	0 m Specific earthing requirements 3)	0,3 m Specific earthing requirements 4)

Common requirements

- L = length of span
- Higher voltage is placed above lower voltage. Bare conductor is placed above covered conductors or cables.

1) Clearance between the lines is stated by the line with the highest system voltage.

2) Allowed if high voltage line ≤ 25 kV and:

- is placed above the low voltage line and the distance between the lines exceeds 2 m
- bare conductor is: min 25 mm^2 for Fe, min 35 mm^2 for Cu, min 62 mm^2 for ACSR, AAC or AAAC
- if high voltage line is provided with an earth conductor, this shall be connected to the insulator attachment
- if high voltage line is provided with an earth conductor located under the phase conductors, the vertical distance between the earth conductor and the low voltage conductor shall be at least 0,3 m
- the wooden distance between exposed conductive parts of the two lines must be at least 1 m or the exposed parts of the high voltage line shall be earthed
- is installed on line posts, the line post insulators must be of massive type
- shall be of class A.

3) The lines shall have a common earthing system.

4) The high- and low voltage lines shall have an interconnected earthing system according to SS-EN 50522.

(ncpt) Table 5.9.6/SE.4 — Minimum clearance to other power lines or overhead telecommunication lines

	Parallel or converging lines on separate supports	
	Supports in parallel or converging overhead lines that are located in vicinity of each other shall if possible be placed where they, if falling, can do so without inflicting damage to the other line. If the above requirement cannot be met, supports shall either be equipped with guys to prevent them from falling or the line shall fulfil the requirements for reinforced lines of type 1. In any case the clearances specified below apply	
Load Case	**Horizontal clearance** between support and nearest live part on the other line.	If the horizontal clearance cannot be fulfilled the **vertical clearance** shall be at least:
Temperature at short-circuit conditions, see Subclause 5.6/SE.2.5		2 m (for U_s < 420 kV) 3 m (for U_s = 420 kV)
All load cases	2 m + S	4 m
Remarks	Clearance between energized part of one line and guy in the other line shall be at least 1.1 times the clearance given in Table 5.8/SE.5.	Overhead line with Us ≥ 100 kV shall not cross over a telecommunication pole with junction or joint box(es).

5.9.7 External clearances to recreational areas (playgrounds, sports areas, etc.)

(A-dev) Table 5.9.7/SE.1 — Minimum clearance to recreational areas

	Line above			**Line in close proximity**	
	Locations where people may be gathering e.g. school yards, sports grounds, camping grounds, bathing- and playgrounds	Areas which normally has no places for spectators e.g. golf courses.	Shooting ranges	Locations where people may be gathering e.g. School yards, sports grounds, camping grounds, bathing- and playgrounds	Shooting ranges
Load Case	Vertical clearance	Vertical clearance	Vertical clearance	Horizontal clearance	Horizontal clearance
All load cases	-	Se Table 5.9.2/SE.1 and 5.9.2/SE.2	-	20 m	at least 20 m
Remarks	It is not permitted to cross school yards, sports grounds, camping grounds, bathing- and playgrounds and places for spectators with power lines.	If measures have been provided against damaging of the power line. The overhead line must be built as reinforced line type 1 or as reinforced line type 2 for lines with nominal voltage not exceeding 25 kV.	It is not permitted to cross shooting ranges with power lines.		The clearance judgement shall include the horizontal distance beside and behind the shooting range including the bullet backstop. The judgement shall also include the visibility of the power line from the firing location.

6 Earthing systems

6.1 Introduction

6.1.1 Purpose

(A-dev)

SE.1

Exposed-conductive-part in overhead line installations shall be earthed. This also applies to extraneous conductive parts that in an events of faults, by induction or influence, can become energized and cause danger of personal injury or property damage.

Outside closed electrical areas equipment and cables shall either be constructed with an earthed intermediate shield or be protected against unintentional direct contact by placing out of reach. An earthed intermediate shield refers to metal enclosures for equipment and screening for cables.

(5 kap. 1 § (ELSÄK-FS 2022:1)).

6.1.3 Earthing measures against lightning effects

(ncpt)

SE.1

Overhead lines for U_s higher than 45 kV should be equipped with entry-protection on a section in the vicinity of the substation. The length of the shield wire, in metres, shall be at least three times the U_s of the line in kV with a minimum length of 200 m. Earthed shield wires, over horizontal erected conductors, normally gives protection against lightning if the shielding angle, measured between a vertical line through the shield wire and a line to the outer conductor, is less than 25 - 30 degrees. Alternatively, the crossarms can be earthed with an efficient longitudinal counterpoise earth wire.

6.1.4 Transferred potentials

(A-dev)

SE.1

Overhead lines connected to systems with system earthings causing earth fault currents exceeding 500 A, shall have been granted permission before the line can be energized. Licences are issued by the Swedish National Electrical Safety Board.

The regulation includes energizing for temporary situations, e.g. for test operations.

(7 and 8 §§ (2017:218), 3 and 4 §§ (ELSÄK-FS 2011:3)).

NOTE For other structures and installations in the area of influence, see also Subclause 6.4.1/SE3 for touch and step voltages.

6.2 Ratings with regard to corrosion and mechanical strength

6.2.1 Earth electrodes

(ncpt)

SE.1

Earth electrodes shall be of specially arranged sheets, wires, pipes or angel bars of copper or hot dip galvanised steel or of wires or rods of copper clad steel.

The minimum cross sections and dimensions shall be in accordance with Table 6.1/SE.1.

(ncpt) Table 6.1/SE.1 - Minimum cross sections of earth electrodes

Material	Type of section	Dimensions
Copper sheet	—	1 mm · 0,5 m^2
Copper wire	Cross section	25 mm^2
Steel wire	Cross section	50 mm^2
Steel tube	Outside diameter	49 mm
Steel bar	Angle	60 x 60 x 6 mm
Copper clad steel wires	Cross section	25 mm^2
Copper clad steel rod	Diameter	14,6 mm

(ncpt)

SE.2 Earth electrodes and earthing conductors

Bare earthing conductors shall above ground level be perspicuous installed in order to be easily visible and accessible to most extent. It shall also be installed so that mechanical and chemical damages can be avoided. Joints shall, if possible, be avoided.

Earthing conductors with cross section less than 50 mm^2 shall be protected against mechanical damage on a height of 1,5 m above ground level and to a depth of 0,5 m into the ground.

In the earthing, where applicable, a bolted current carrying connector shall be installed so that the earth electrode can be disconnected from the earth conductor in order to measure the individual resistance of the earth electrode. The connector shall not be able to be opened without any tools.

6.2.2 Earthing and bonding conductors

(ncpt)

SE.1

Earthing conductor shall be of copper, hot dip galvanised steel or copper clad steel. Above ground it even may be of aluminium or aluminium alloy.

Shield of copper or lead/steel band in power cables, in accordance with the Swedish Standard for power cables with U_s greater than 1 kV, may be used as earthing conductor for the protection and system earthing.

Earthing conductor shall be designed so that the maximum earth fault current will not cause any dangerous heating at the conductor or its environments.

The minimum cross section shall be in accordance with Table 6.2/SE.1.

(ncpt) Table 6.2/SE.1 - Minimum cross sections of earthing conductor

	Copper mm^2	Steel mm^2	Copper clad steel mm^2	Aluminium or alloyed aluminium mm^2
Earthing conductor	25	50	25	-
Other conductor for earthing purpose:				
Above ground level	10	25	25	30
Into ground	25	50	25	-

6.4 Dimensioning with regard to human safety

6.4.1 Permissible values for touch voltages

(A-dev)

SE.1

Overhead lines connected to systems with system earthings causing earth fault currents exceeding 500 A, shall be disconnected within 0,5 s.

Overhead lines connected to systems with system earthings causing earth fault currents of 500 A or below, shall be disconnected within 5 s.

(5 kap. 4 § (ELSÄK-FS 2022:1)).

6.4.2 Touch voltage limits at different locations

(A-dev)

SE.1

Overhead lines of reinforce line type 2, lines with covered conductors or lines with overhead insulated cable system without an earthed intermediate shield, connected to systems with system earthings causing earth fault currents of 500 A or below shall have protection devices against earth faults with highest possible sensitivity for detection of earth faults. An automatic device shall disconnect for earth fault detections up to 5000 Ω.

For lines other than mentioned above and with a nominal voltage below 25 kV connected to systems with system earthings causing earth fault currents of 500 A or below, shall have protection against earth fault. An automatic device shall disconnect for earth fault detections up to 3000 Ω. Within areas not covered by a detailed development plan (rural areas), the overhead line can include a few spans of covered conductors.

(5 kap. 5 and 6 §§ (ELSÄK-FS 2022:1)).

(A-dev)

SE.2

For lines connected to systems with system earthing causing earth fault currents exceeding 500 A, the earth potentials due to the earth faults provide adequate safety if the voltage does not exceed 220 V over a simulated human body resistance of 1000 Ω at locations where no additional resistance is considered.

(5 kap. 7 §§ (ELSÄK-FS 2022:1)).

6.4.3 Basic design of earthing systems with regard to permissible touch voltage

(ncpt)

SE.1

Figure 6.2, remark 5: Sweden has unpredictable soil conditions and with high or very high soil resistivity.

(ncpt)

SE.2

Figure 6.2, remark 8: Measures for poles, towers, supports and anchors to reduce touch and step voltages in low impedance earthed systems can be potential grading rings buried at 0,5 m at a distance of 1 m from earthed part or insulation of earthed parts reachable from the ground. Additional measures may be required, e.g. at locations according to Subclause 6.4.2, example 1.

(A-dev)

SE.3

NOTE See also 6.1.4 Transferred potential SE.1.

6.4.4 Measures in systems with isolated neutral or resonant earthing

(ncpt)

SE.1

This clause is not applicable for Swedish overhead lines, see 6.4.1, SE.1.

7 Supports

7.1 Initial design considerations

(ncpt)

SE.1

The general requirements of the Eurocodes should be considered together with the EKS.

7.2 Materials

7.2.1 Steel materials, bolts, nuts and washers, welding consumables

(ncpt)

SE.1

In EN 1993-1-1 3.2.1: Option a) apply.

Table 3.2 of EN 1993-1-1 shall be modified as shown below

Target value of Z_{Ed} according to EN 1993-1-10	Required value of Z_{Rd} expressed in terms of design Z-values according to EN 10164
$Z_{Ed} \leq 10$	-
$Z_{Ed} > 10$	Z35

7.2.6 Wood

(ncpt)

SE.1

Scots pine (Pinus Sylvestris) is recommended.

7.3 Lattice steel towers

7.3.1 General

(ncpt)

SE.1

Lattice steel towers should be fabricated according to relevant parts of SS-EN 1090-2.

The provision in SS-EN 1090-2, 8.2.4 regarding double washers in single lap connections need not be considered.

7.3.3 Materials

(ncpt)

SE.1 Minimum thickness of material in steel members

Minimum thickness of material in steel members shall be 3 mm for open sections and 2,5 mm for hollow sections. Hollow sections shall be equipped with a drainage system.

7.3.6 Ultimate limit states

7.3.6.1 General

(ncpt)

SE.1

The partial factor γ_M shall be taken as follows:

Resistance of cross-section areas in tension to fracture $\gamma_{M2} = 1,2$

resistance of bolted connections $\gamma_{M2} = 1,2$

resistance of riveted connections $\gamma_{M2} = 1{,}2$

For other γ_M see EKS.

(ncpt)

SE.2

Annex J should be used where it is applicable.

7.3.6.3 Tension, bending and compression resistance of members

(ncpt)

SE.1 Alteration of 1)

Tension resistance shall be calculated according to the following formula:

$N_{sd} \leq A_{net} \cdot f_u / \gamma_{M2}$

For angles connected through one leg, tension resistance should be calculated using the method according to the provisions of Annex J.3.

7.3.6.4 Buckling resistance of members in compression

(ncpt)

SE.1

Compression members in lattice towers shall be designed using the method according to the provisions of Annex G and Annex H of EN 1993-3-1.

7.3.8 Resistance of connections

(ncpt)

SE.1

Bolted connections in lattice towers shall be designed using the method according to the provisions of Annex J.5 and J.5/SE.1. For bolts in tension the method according to the provisions of Clause 3 of EN 1993-1-8 can also be used.

Bolt holes should be formed according to EN 1090-2 with the addition that drilling of holes is recommended for holes in steel thicker than 13 mm.

Nuts shall be locked by punching or chisel hack on the threads or in another secure way.

7.4 Steel poles

7.4.1 General

(ncpt)

SE.1

EKS shall be considered together with EN 1993-1-1.

(ncpt)

SE.2

Steel poles should be fabricated according to relevant parts of SS-EN 1090-2.

7.4.6.1 Ultimate limit states, General

(ncpt)

SE.1

The partial factor γ_M for EN 1993-1-1 shall be taken as follows:

resistance of net section at bolt holes $\gamma_{M2} = 1{,}2$

No deflection limits apply, if not otherwise stated in the Project Specification.

7.4.8.1 Connections, Basis

(ncpt)

SE.1

The partial factor γ_M shall be taken as follows:

resistance of bolted connections γ_{M2} = 1,2

resistance of welded connections γ_{M2} = 1,2

For other γ_M see EKS.

7.4.8.2 Bolts (other than holding-down bolts)

(ncpt)

SE.1

See 7.3.8/SE.1.

7.5 Wood poles

7.5.1 General

For sawn structural timber the design resistance shall be calculated in accordance with EN 1995-1-1 and EKS.

7.5.3 Materials

(ncpt)

SE.1

Materials shall comply with 7.2.6/SE.1.

7.5.5 Ultimate limit states

7.5.5.2 Calculation of internal forces and moments

(ncpt)

SE.1

Guyed or self-supporting poles that are embedded in ground or attached to rock can be calculated with first order theory. The initial crookedness need not to be considered in the design of these poles if it is within a theoretical straight line drawn from centre of the top to the centre of the butt is inside the pole. The internal forces, moments and stresses shall be determined using elastic analysis.

7.5.5.3 Resistance of wood elements

(ncpt)

SE.1

For round timber and timber sleepers of Pinus Sylvestris the design values, f_d, of resistance in ultimate limit states (load combination 1) shall be in accordance with Table 7.2/SE.1.

(ncpt) Table 7.2/SE.1 — Design value for timber poles

Type of stress in a cross section	Design value (MPa)
bending	30
shearing	2,6
compression, without risk of buckling - perpendicular fibres	4,0
compression, without risk of buckling - along fibres	14,5
modulus of elasticity - for bending [1)]	10000
modulus of elasticity - for Euler-buckling	5200

NOTE 1 The same values can be used in serviceability limit states.

For supports exposed to permanent bending loads in load case 2a in accordance with 4.12.2/SE.2.2 the design value for bending is 15,7 MPa.

For demarcation support of timber poles exposed to bending loads the design value for bending in ultimate limit state (load combination 1) is 43 MPa in load case 5b in accordance with 4.12.2/SE.4.8.

7.5.5.4 Decay conditions

(ncpt)

SE.1 Decay

The resistance of timber poles can be reduced by decay that normally arises in the ground level. The decay can be of different types and the poles are affected differently depending on impregnation type, the geographical location and the type soil.

The design value given above for bending considers inspection intervals and takes into account changes in strength caused by decay etc. For poles with decay the design bending resistance can be increased by 33 % for the calculation with the undamaged cross section. The design buckling resistance can be calculated with the modulus of elasticity for Euler-buckling increased by 33 %. In this case the diameter of remaining undamaged wood at ground level shall not be less than the top diameter of the pole. Increase of design resistance for bending and buckling is not allowed for poles at crossings with roads, railways or other underlying overhead lines.

If a pole is reinforced due to decay the elasticity and strength shall be restored to the values of the undamaged pole. Remaining undamaged wood within the defected area shall not be regarded in the design of the reinforcing.

The material in the reinforcing shall be designed in accordance with reference codes in Clause 7/SE. For full scale testing see 7.11.

7.5.7 Resistance of connections

(ncpt)

SE.1

For the design of steel bars and bolts see 7.3 and 7.3/SE.

7.5.8 Design assisted by testing

(ncpt)

SE.1

For design carried out by calculation and verified by test, the test load $F_{test,R}$ shall be determined from $F_{test,R} = \gamma_M \cdot F_{R,d}$ with $\gamma_M = 1{,}7$ for resistance of bending. $F_{R,d}$ is the design load for the ultimate limit state (load combination 1).

For design carried out only by testing the evaluation shall be done considering the number of tests.

7.6 Concrete poles

7.6.1 General

(ncpt)

SE.1

EKS shall be considered together with EN 1992-1-1.

Concrete poles shall be made in a factory. The manufacturer shall meet the requirements for control in accordance with SS-EN 13670.

The finished pole surface shall be smooth. Cavities can occur depending on the casting technique. The total area of cavities shall be less than 5 cm^2 per 100 cm^2 of the pole surface. The average depth of cavities shall be less than 3 mm. Pole with larger area of cavities can be accepted if concrete cover to links, determined by measurement, is at least 10 mm plus the average depth of cavities.

Repair of blowholes may be accepted if the reparation results in the same lifetime as the pole. Hole after form tie shall be sealed with concrete plug and water-cement paste.

The top shall be provided with a cover of concrete or concrete casting.

The inside and outside of the pole surfaces shall be coated, for location in aggressive soil with pH less than 4,5 or content of lime aggressive carbon acid larger than 60 mg/dm^3, with bitumen or similar on the butt part up to 0,5 m over ground level.

Marking of the pole shall be placed 4 m from the butt end and show manufacturer, date of manufacturing, weight and if required type mark. The marking shall be resistant.

7.6.2 Basis of design

(ncpt)

SE.1

The effect of loads shall include moments from the design value of all vertical loads including dead weight, i.e. second order theory.

For Load case 5a in accordance with 4.12.2/SE.2.7 the load partial factor γ_Q can be reduced to $\gamma_Q = 1{,}20$ for the conductor tension load in tangent and angle supports.

7.6.3 Materials

(ncpt)

SE.1

The concrete strength shall be C40/50 - C50/60 and have a water-cement ratio of maximum 0,45. Higher strength may be used after testing in accordance with EN 1992-1-1. Non spun poles shall have a percentage of air to be frost resistant.

If the strength of the concrete, at delivery, is lower than the final strength the lower value shall be used for resistance and crack calculations.

Concrete cover for industrial manufacturing shall be at least 15 mm for transverse reinforcing and 20 mm for longitudinal reinforcing with bar diameter of maximum 16 mm. For a larger bar diameter see EN 1992-1-1 and EKS.

7.6.4 Ultimate limit states

(ncpt)
SE.1

The prestressing force shall be considered both before and after relaxation of the steel.

The boxed values for γ_{Pt} shall be 1,0 respectively 1,2.

For buckling resistance the design value of Euler load shall be divided by 1,3. The Euler load shall be calculated with the design value of modulus of elasticity, i.e. E_{ck} divided by γ_{MC} .

7.6.5 Serviceability limit states

(ncpt)
SE.1

No limit for Maximum deflection, if not otherwise stated in the Project Specification.

Tangent poles: Maximum width of cracks, in case of reinforced concrete 0,2 mm.

Other poles: Maximum width of cracks, in case of reinforced concrete 0,1 mm.

For tangent and angle poles in Load case 5a in accordance with 4.12.2/SE.2.7 there are no limits for the width of cracks in reinforced concrete or in pre-stressed concrete.

The limits for widths of cracks are the same for the load cases transport, erection and conductor stringing as for the wind loading cases.

No cracks shall be found in pre-stressed concrete poles as the result of the pole being subject to loads during wind, transportation, erection and conductor stringing. The pre-stressing force shall be considered both before and after relaxation. For transport and erection the partial factor for dead weight γ_G shall be taken as for construction loads.

The pole can be considered non-cracked for concrete tension less than f_{ctm}, where f_{ctm} is the mean value of concrete tensile strength in accordance with EN 1992-1-1.

7.6.6 Design assisted by testing

(ncpt)
SE.1

For design carried out by calculation and verified by test, the test load $F_{test,R}$ shall be determined from:

- for bending test with rupture in concrete $F_{test,R} = \gamma_{MC} \cdot F_{R,d}$
- for bending test with rupture in steel $F_{test,R} = \gamma_{MS} \cdot F_{R,d}$
- for instability test $F_{test,R} = 1,15 \cdot \gamma_{MC} \cdot F_{Sd}$

F_{Sd} is the design load for the ultimate limit state (load combination 1).

No limit for maximum deflection and maximum residual deflection, if not otherwise stated in the project specification.

7.7 Guyed structures

7.7.3 Materials

(ncpt)
SE.1

The guy steel wire strands shall be in accordance with the Swedish Standards SS 424 08 06.

The minimum breaking strength of the guy shall be 30 kN.

NOTE SS 424 08 06 gives the requirements for manufacturing of zinc-coated steel wire strands.

7.7.4.1 Ultimate limit states, Basis

(ncpt)

SE.1

The partial factor γ_M for the guy wire is

- γ_{M2} = 1,40 for tangent supports
- γ_{M2} = 1,55 for permanent loaded guy, e.g. angle and terminal supports.

The minimum loss factor K_e for wedge guy anchor clamp shall be 0,90 for guy anchor clamps type tested with the relevant guy wire.

The loss factor shall be proven by sample test given by Inspection Certificate type 3.1 in accordance with SS-EN 10204.

For partial factors for guy insulators, see 10.7/SE.1.

7.7.4.2 Calculation of internal forces and moments

(ncpt)

SE.1

Amendment to fourth paragraph:

For a lattice column hinged in both ends the additional shear force can be calculated from the bending moments resulting from the out of straightness according to 7.7.4.3 and the deflections caused by external loads and second order effects.

7.7.4.3 Second order analysis

(ncpt)

SE.1

Amendment to second paragraph

The initial out of straightness for other materials than steel and timber shall be selected in accordance with the material design standard.

(ncpt)

SE.2

Amendment to fourth paragraph

The eccentricity at the bottom end section can be up to the radius of the underlying washer, if not otherwise is stated in the Project Specification.

(ncpt)

SE.3

Amendment to fifth paragraph

If an end eccentricity at the ends of hinged lattice legs is used to compensate for the bending effects of the wind load on the leg, the support shall be checked as follows: full wind load on crossarms and conductors according to 4.3.4/SE.1 together with a simultaneous reduced wind load, $0{,}25 \cdot q_p$ (h) on the legs and guywires.

7.7.6 Design details for guys

(ncpt)

SE.1

The design value for modulus of elasticity shall be 180000 MPa for guy steel wire strands in accordance with SS 424 08 06.

Measures shall be taken to avoid electrification of guys.

Guys shall be arranged in such a way that they will not touch energized conductors in case of breakage or temporary loss of tension.

Correct guy arrangement may be earthed guys and proper fault protection in the electrical installation. In supports made from insulating material (wood, fibre reinforced polymer), where appropriate insulation between guys and energized parts is provided guys need not be earthed.

Appropriate insulation shall fulfil the requirements of Table 5.8/SE.5. For systems with earth fault current above 500 A, 5.3/SE.1 also apply.

7.8 Other structures

(ncpt)

SE.1.1 Glulam poles

Glulam poles shall be designed and manufactured in accordance with EN 1995-1-1 and EKS.

Pine wood (*Pinus species*) is recommended, preferably with a large sapwood portion. The glue shall be water and weather resistant and shall endure temperatures from -50 °C to +200 °C. Heartwood shall be avoided in the surface layer. End surfaces should be protected against moisture ingress.

The anti-decay treatment shall not be deteriorated by surface plane-off or other shaping performed after impregnation. New holes and other changes which cannot be avoided are allowed if the surface is treated afterwards in an appropriate manner.

The effect of loads shall include moments from the design value of all vertical loads including dead weight by using an interaction formula or second order theory calculation.

The strength modification factor k_{mod} shall be taken in accordance with EN 1995-1-1 Subclause 3.1.3 with service class 2 for laminated timber above the ground surface and service class 3 for laminated timber buried in soil. The load-duration classes shall correspond to the imposed loads as follows:

Load	Load-duration class
Security load	Instantaneous
Wind load and conductor tension derived from wind load.	Short term action
Ice load and conductor tension derived from ice load.	Medium term action
Dead weight and conductor tension derived from conductor dead weight only at 0 °C temperature.	Permanent action

The pole shall be marked with glue class, strength class, impregnation class, manufacturer and manufacturing number and year. The marking shall be placed 4 m from the butt-end.

(ncpt)

SE.1.2 Aluminium

The calculation of resistance and manufacturing of supports made of aluminium shall be in accordance with SS-EN 1999-1-1 and EKS.

(ncpt)

SE.1.3 Fibre-reinforced polymer poles

(ncpt)

SE.1.3.1 Basis of design

1) The rules given in Clause 3 “Basis of design” are applicable.
2) Unless otherwise specified, it is not necessary to consider seismic effects, fatigue or fire resistance.

(ncpt)

SE.1.3.2 Material and durability

Poles are to be made from fibre-reinforced polymer composite where the polymer is a thermoset or a thermoplastic polymer resin matrix. Thermoplastic polymer resin matrixes shall fulfil the creep requirements of 7.8/SE.1.3.3. The resin system and the fibre-reinforcement shall have mechanical and durability characteristics that are adequate for environment and a design life of 60 years. The processing characteristics of the resin system shall be suited to the manufacturing process and fibre reinforcement. Filler content shall not adversely affect the mechanical and durability properties of the resin.

The structural load bearing fibre-reinforced polymer composite material needs to be protected from weather and UV-degradation. For example, using a UV-stable resin or a UV-stable outer top layer e.g., paint/coating/liner/housing. The UV resistance shall either be verified with a UV-test carried out on pole wall samples (alternative 1) or on material samples (alternative 2) taken from the outer top layer on the pole applied on the pole for UV-weather protection. Equivalent UV-test can be agreed between the manufacturer and the user/buyer.

NOTE More information can be found in CIGRE Technical Brochure No. 488 and No. 818.

SE.1.3.2.1 UV-test on pole wall samples (alternative 1)

Three samples from a pole shall be exposed to UV light on the outer surface for 10000 h in accordance with ISO 4892-3:2016, UVA-340, Typical cycle a), ISO 4892-2:2013, Method A, Cycle 1 or equivalent UV exposure method. The thickness of the samples shall be thinner than or equal to the pole wall thickness.

Acceptance criteria: No signs of fibre bloom, surface cracking, crazing or delamination on the UV exposed outer surface.

SE.1.3.2.2 UV-test on top layer (alternative 2)

Samples taken from the top layer (paint/coating/liner/housing) applied on the poles to protect the structural load bearing fibre-reinforced polymer composite material. Alternatively, samples can also be taken from a sheet/plate made from the top layer material. The thickness of the samples shall be thinner than or equal to the minimum thickness of the top layer on the poles.

Tensile test according to ISO 527-2, ISO 527-3 or equivalent method shall be performed on unexposed specimens and on specimens exposed to UV light for 2000 h in accordance with ISO 4892-3:2016, UVA-340, Typical cycle a), ISO 4892-2:2013, Method A, Cycle 1 or equal UV exposure method. The variation of the tensile strain at break, $\Delta\varepsilon_{\mathrm{b}}$, shall be calculated as:

$$\Delta\varepsilon_{\mathrm{b}} = \frac{\varepsilon_{\mathrm{b1}} - \varepsilon_{\mathrm{b0}}}{\varepsilon_{\mathrm{b0}}}$$

where

$\varepsilon_{\mathrm{b0}}$ is the arithmetic mean of at least five tensile strain at break results before UV- exposure

$\varepsilon_{\mathrm{b1}}$ is the arithmetic mean of at least five tensile strain at break results after UV-exposure.

Acceptance criteria: The variation of the tensile strain at break, $\Delta\varepsilon_{\mathrm{b}}$, shall be less that ±30 %.

(ncpt)

SE.1.3.3 Creep requirements for thermoplastic polymer resin matrixes

Suppliers shall be able to provide documentation verifying that the creep characteristics of the pole are such that they do not adversely affect the intended purpose of the pole.

(ncpt)

SE.1.3.4 Temperature requirements

Poles shall be able to withstand loadings in accordance with this standard up to a material temperature in accordance with 4.7/SE.1 except for load case 1a for which +40 °C apply. This capability shall be verified by testing.

NOTE: This may be performed by verifying that the compression strength at +40 °C, of a sample taken from a pole identical to a pole which has been subject to testing in accordance with 7.8/SE.1.3.11, is higher or equal to than what is derived from the test load.

The maximum short duration temperature in accordance with Clause 9 of any installed down lead ground wires shall be considered for poles particularly in lines with earth fault current above 500 A.

(ncpt)

SE.1.3.5 Surface finish

Poles shall have a smooth finish with a suitable surface coating to prevent fibres breaking out of the surface during the design life of the pole.

(ncpt)

SE.1.3.6 Cut edges

Provided that the supplier can provide documentation, to verify that cut edges at the pole ends or to openings in the pole, made after completed curing, can perform with no sealing, sealing is not required to be applied on such surfaces. The provided documentation shall include the combined long term effects of UV radiation, temperature variations and humidity variations on exposed surfaces of the laminate or to surfaces with no sealing in openings with installed hardware such as stud bolts etcetera.

If no such documentation is provided all cut edges of the pole ends or to openings in the pole, made after completed curing, shall be sealed to prevent ingress of water or any other contaminants. Sealing shall be through the application of the parent resin or a suitable alternative.

(ncpt)

SE.1.3.7 Marking

Poles shall at 4 m from butt be clearly and durably marked with:

1) The name of the manufacturer
2) The year of the manufacture
3) A unique product code

For poles composed of sections each section shall be marked with a unique product code.

NOTE The marking can be formed in the material, by painting or by securely fixed label

(ncpt)

SE.1.3.8 Structural analysis

1) The internal forces and moments in any transverse section of the structure shall be determined normally using linear elastic global analysis with respect to the material behaviour.
2) Second order theory (P-Delta effect), taking into account the influence of the deformation of the structure, shall be used for the global analysis, thus considering the non-linear geometric behaviour.

(ncpt)

SE.1.3.9 Ultimate limit states

(ncpt)

SE.1.3.9.1 General

1) The partial factor, γ_M, applicable for resistance of cross section areas and resistance of net section areas (reduced for area of bolt holes) shall, in accordance with EN 1990, D7, be derived from the test results obtained when the load-bearing capacity of a pole was established. This requirement will be fulfilled by considering the standard deviation divided with the mean value (= coefficient of variation, COV, or “*V*”) of the load-bearing tests cross-referenced with the number of poles tested in accordance with Table 7.8/SE.1.3.9.1.

(ncpt) Table 7.8/SE.1.3.9.1 — γ_M for fibre-reinforced polymer poles

COV	Number of poles tested				
	5	10	20	30	∞
0,20	n.a.	6,29	2,38	2,10	1,71
0,18	n.a.	3,48	1,98	1,81	1,56
0,16	n.a.	2,49	1,72	1,61	1,44
0,14	n.a.	1,98	1,54	1,46	1,34
0,12	12,42	1,68	1,40	1,35	1,26
0,10	3,57	1,47	1,30	1,26	1,20
0,08	2,19	1,32	1,21	1,19	1,15
0,06	1,63	1,21	1,14	1,13	1,10
0,04	1,32	1,13	1,09	1,08	1,06
0,02	1,13	1,06	1,04	1,04	1,03

NOTE The above table is based on the assumption that there is no prior knowledge about the coefficient of variation, i.e. “V_x unknown” in accordande with EN 1990, D7. Provided that the requirements of EN 1990, D7 are fulfilled, other values of, γ_M, apply for the case “V_x known” which may be derived in accordance with EN 1990, D7.

2) For resistance of bolted connections see Subclause 7.8/SE.1.3.10

3) The deflection at the ultimate limit state (load combination 1) for load cases 1-3 and 6 according to 4.12.2/SE shall be equal or less than that of a corresponding wood pole fulfilling the requirements of this standard. For a self supporting pole this requirement is fulfilled if the deflection is less than 15 % of the pole height from the ground line. For guyed poles with the attachment of the guy below the load point, the deflection requirement apply for the length of the unguyed part.

(ncpt)

SE.1.3.9.2 Resistance of cross section areas

1) The effective cross section area shall take into account local buckling.

2) Any effect, regarding strength and deflection, of the cross section becoming oval due to applied loading shall be considered.

(ncpt)

SE.1.3.9.3 Serviceability limit states

1) Appropriate limiting values of deformations and deflections shall be agreed between the client and the designer.

2) The serviceability limits for fibre-reinforced polymer poles are related to the pole geometry and shall be defined in compliance with the required electrical clearances (to ground and to structure) as given in Clause 5 “Electrical Requirements”.

(ncpt)

SE.1.3.10 Resistance of connections

(ncpt)

SE.1.3.10.1 Basis

1) All connections shall have a design resistance such that the structure remains effective, and that the basic design requirements given in Clause 3 “Basis of design” are satisfied.

2) The partial material factor, γ_M for resistance of bolted connections shall be taken as follows:

bolts in shear or bearing	γ_{Mbs} = 1,3
bolts in tension	γ_{Mbt} = 1,3

(ncpt)

SE.1.3.10.2 Slip joint connections

1) Slip joint connection shall be able to withstand the loadings derived from the actions in accordance with Clause 4 which shall be verified by either calculation or testing.

2) When modelling the pole considering a global elastic analysis, only the nominal inside male section in the splice area shall be considered for resistance.
3) The assembly is carried out on site. To take into account variations in thickness, the minimum effective length of jointing shall be greater than 2 times the maximum average diameter of the female section.
4) However, the sum of the slip tolerances at each joint shall comply with the pole length tolerance defined in the Project Specification.
5) The jointing force shall exceed the maximum factored design vertical compressive force at joint level. Alternatively the joints may be reinforced to withstand the factored design vertical compressive load to eliminate possible joint movement.
6) When necessary, anchoring devices on either side of the slip joint shall be provided on the pole in order to ensure on the site a proper splicing using hydraulic jacks or pulling devices according to the supplier recommendations.

(ncpt)

SE.1.3.10.3 Direct embedding into the concrete

1) Pole-to-foundation connection shall be made preferably by direct embedding of the bottom part of the FRP-pole into the concrete.
2) The length of the section of the pole embedded into the concrete shall be determined using a linear loads distribution in conformity with requirements of EN 1992-1-1.
3) Due consideration shall be given to the buckling of the FRP section if the part of pole embedded is not filled with concrete.

(ncpt)

SE.1.3.10.4 Base plate and holding-down bolts

Connections between concrete foundations and FRP-poles utilizing metallic base plates shall fulfil the requirements of 7.4.8.7

(ncpt)

SE.1.3.11 Design assisted by testing

As outlined in 7.8/SE.1.3.9.1 the structural design resistance of fibre-reinforced polymer poles depends on the characteristic strength (5% lower exclusion limit in accordance with EN 1990, D7 or EKS 10, Table B-5) and unfavourable deviations from the characteristic strength established by full-scale load testing. Therefore fibre-reinforced polymer poles shall undergo static bending testing as specified in applicable parts of SS-EN 14229 Annex C for:

1) Each pole type.
2) Each type of manufacturing process.
3) Each type of polymer resin matrix

A pole type is distinguished by the diameter, length, taper, material thickness and the fibre-reinforcement content defined by percentage by weight.

For the purpose of quantifying testing for poles composed of sections each pole section can be considered as a pole type. For slip joint connections SE.1.3.10.2 also apply.

7.9 Corrosion protection and finishes

(ncpt)

SE.1 Painting on steel

Since in general painting is an inferior corrosion protection compared to galvanizing it is recommended to increase the thickness of material with some millimetre for painted parts. This is important in marine atmosphere and in corrosive industrial atmosphere where it must be considered if painting only is sufficient as corrosion protection.

7.9.2 Galvanizing

(ncpt)

SE.1

EN ISO 14713-2 shall be considered in the design and manufacture of parts to be galvanized.

Zinc coating shall be in accordance with SS-EN ISO 1461 with minimum coating thickness in accordance with Table 7.9.2/SE.1.

Table 7.9.2/SE.1

Thickness of the steel	**Fe/Zn 95**		**Fe/Zn 115**		**Fe/Zn 215**	
	Local coating thickness	Average coating thickness	Local coating thickness	Average coating thickness	Local coating thickness	Average coating thickness
mm	µm	µm	µm	µm	µm	µm
t > 6	85	95	100	115	190	215
t ≤ 6	70	85	85	95	115	140

Fe/Zn 95: for steel in air
Fe/Zn 115: for wedged rock anchors/eyebolts
Fe/Zn 215: for steel in ground

Zinc coating on bolts shall be in accordance with SS-EN ISO 10684. Galvanized threads shall be undersized in accordance with ISO 965-4. Members with threaded parts shall fulfil Fe/Zn 95, Fe/Zn 115 and Fe/Zn 215 except in the threads and on a length of maximum five times the bar diameter from the end of the threads, where the zinc coating shall be in accordance with SS-EN ISO 10684.

Damages in galvanizing surface can be repaired by spray galvanizing or by painting twice with zinc rich paint, zinc powder 92-95 % of dry weight. The damaged surface shall be carefully cleaned by sand blasting or similar and dried and preheated before treatment.

Galvanizing of steel wires shall be in accordance with SS-EN 50189, Class A zinc coating.

In marine atmosphere and in corrosive industrial atmosphere it must be considered if galvanizing only is sufficient as corrosion protection.

7.9.3 Metal spraying

(ncpt)

SE.1

The zinc layer shall not be less than the requirements for hot-dip galvanizing.

7.9.6 Use of weather-resistant steels

(ncpt)

SE.1

If weather-resistant steel shall be used the effect of rust shall be considered in accordance with the recommendations from Korrosionsinstitutet: Bulletin nr 94 and nr 97.

7.9.7 Protection of wood poles

(ncpt)

SE.1 Protection of wood poles, sleepers and glulam poles

Wood poles, sleepers and glulam poles shall be impregnated to fulfil penetration and retention requirements. The penetration requirement to be fulfilled is class NP5 of EN 351-1. The retention requirement to be fulfilled shall correspond to hazard class UC4 of SS-EN 335. For glulam the retention requirement in ground and one metre above ground into 20 mm depth from the wood surface is to be fulfilled by impregnation with both water-borne preservative to class UC4 and with creosote oil to class UC4.

Impregnation shall be checked in accordance with NTR Dokument 3.

7.10 Maintenance facilities

7.10.3 Safety requirements

(ncpt)

SE.1

Supports located in areas where unauthorized climbing without the use of climbing gear may be expected shall be equipped with anti-climbing devices. Such areas include areas where children and youth stay, as in the vicinity of schools, sport areas and playgrounds. Anti-climbing devices shall typically be installed at 2,5 m above ground level.

8 Foundations

8.1 Introduction

(ncpt)

SE.1 Eurocodes

The general requirements of EN 1997-1 (Sections 1 to 5) and EN 1997-2 should be considered together with EKS.

Structural design of concrete, steel, and wood, foundations shall fulfil the applicable EN standard and EKS-regulation.

(ncpt)

SE.2 Concrete Foundations

Concrete quality class for foundations shall be minimum C25/30. Higher quality class may be required by the exposure class. For the evaluation of serviceability limit state requirements, such as concrete crack limitations, load combination 2 of 4.13/SE.1 apply. Still air at 0 °C temperature and initial conductor tension may be assumed.

(ncpt)

SE.3 Steel Foundations

Steel shall effectively be protected against rust. The probability of corrosion is in general higher in soil than in air and the corrosion process is considerably more complicated. The selection of corrosion protection type, hot-dip galvanising, asphalt or painting shall if possible be made after that an investigation which characterise the soil has been performed.

A steel foundation located in soil corrodes in different extents depending on the soil conditions. In well-drained sand or gravel or in soil with limited ground water flow the probability of corrosion damages is low. It is increased with increasing soil humidity and ground water flow. High content of dissolved salts results in increased conductivity which will increase the probability of corrosion damages. As will an increased ground acid content.

Hot-dip galvanising will give an adequate corrosion protection in most soil types. In moderate aggressive soil well performed hot-dip galvanising is sufficient. In more aggressive soil additional protection is required, e.g. a thicker zinc coating, a layer of bitumen or an increase of member thickness. The latter will require some millimetre increased thickness.

In frost-susceptible soil painted parts shall be avoided due to the risk of damage caused by frost heave.

Regarding corrosion protection, see 7.9 and 7.9/SE.1.

(ncpt)

SE.4 Wood foundations

Wood shall be impregnated if it is not installed in water or in soil with the ability to protect the wood against mouldering. This is the case with clay, slime or mud which have pores complete filled with water and with such a consistence that air supply to the wood is prevented.

8.2 Basis of geotechnical design

8.2.2 Geotechnical design by calculation

(ncpt)

SE.1 General

Unless otherwise specified in this NNA or in part 1 the requirements and methods of EN 1997 are to be applied together with EKS. For partial factors for actions, Table 4.7/SE.1 and Table 4.7/SE.2 apply.

The concrete specific weight forces resisting uplift and overturning shall assumed to be 23 kN/m^3 above the ground water table and 13 kN/m^3 below.

The safety for uplift and overturning may need to be increased if a careful soil investigation has not been performed, particularly for angle and terminal supports and for supports which are sensitive to uneven settlements.

Back-filled soil will not immediately regain the soil characteristics of virgin soil even at careful compacting. If the foundation is subject to large overturning or uplift loads before the back-fill is consolidated, then this shall be considered in the calculation.

Rock foundations shall be designed to withstand the applicable loadings, uplift, compression and shear. It shall be securely anchored by the means of anchor bolts and the strength of the rock shall be considered so that the compression capacity is not exceeded. The design value of the pull out resistance of anchor bolts shall be assessed in accordance with EN 1997 Clause 8. The partial resistance factors (γ_R) of Table A.12 for pre-stressed anchorages may also be used for non-pre-stressed anchorages.

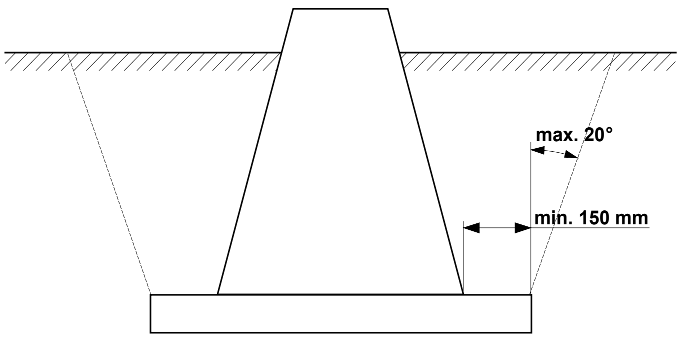
(ncpt)

SE.2 Pad and chimney foundations subject to mainly vertical uplift loads

These requirements apply for pad and chimney foundations. For other types of foundations, e.g. piled and rock foundations, EN 1997 apply. The uplift resistance shall be at least 0,9 times the design load calculated in ultimate limit states (load combination 1). For permanent tension loaded foundations for e.g. angle and terminal supports the resistance shall be at least 1,05 times the design load. Applicable partial factor for soil density used for derivation of uplift resistance is 1,0.

The uplift resistance is derived from the dead weight of foundation and soil. For soils and foundations below the ground water table the effect of buoyance shall be considered. Depending on soil characteristics the resistance shall be calculated with various frustum angles, however maximum 20° see Figure 8.1/SE. In soft soil the angle shall be reduced, in exceptional cases to 0°. Soil parameters are to be taken in accordance with 8.3/SE.1.

If the back-fill is replaced by soil with higher specific weight force, then the back-fill shall correspond to an inverted pyramid considering the applied frustum angle.



(ncpt) Figure 8.1/SE.1 - Uplift foundation

The dimensions of concrete foundations subject for uplift, may alternatively be assessed in accordance with annex M.2 and corresponding paragraphs of this NNA.

(ncpt)

SE.3 Pad and chimney and block foundations subject to mainly overturning moment

These requirements apply for pad and chimney and block foundations. For other types of foundations, e.g. piled and rock foundations, EN 1997 apply. The overturning resistance shall be derived from relevant soil parameters such as cohesion, angle of internal friction and the dead weight of soil and foundation. For soils and foundations below the ground water table the effect of buoyance shall be considered. Design values for the soil parameters may be calculated with partial factor γ_M = 1,0. If the back-fill is replaced by soil with higher specific weight force then the back-fill shall correspond to an inverted pyramid considering the applied frustum angle.

The overturning resistance of foundations shall be at least 0,9 times the design load calculated in ultimate limit states (load combination 1). For self-supporting angle and terminal supports the resistance shall be at least 1,05 times the design load.

For wood poles see 8.2.3/SE.1.

(ncpt)

SE.4 Second order theory analysis

For supports designed considering second order theory the reactions from this analysis shall be used.

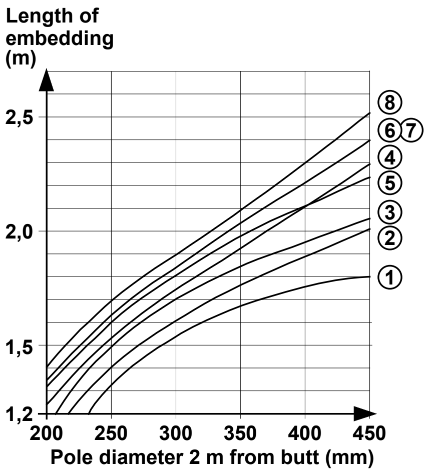
8.2.3 Design by prescriptive measures

(ncpt)

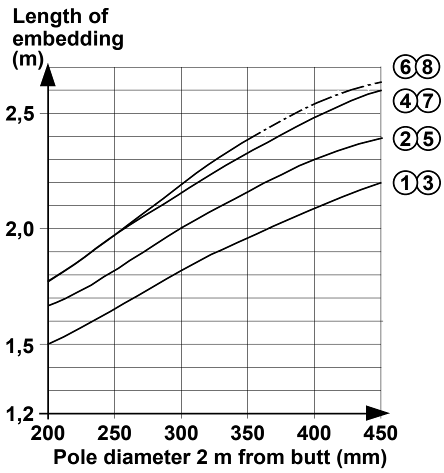
SE.1 Timber poles

Foundations for single or portal timber supports in firm or moderately firm ground are not generally required. In soft soil reinforcement may be required, e.g. back-filling around the pole with gravel or macadam or by sheet piling.

The required embedded length of a self-supporting timber pole is depending on the pole diameter 2 m from butt and the soil type, see Figure 8.2/SE.1 for poles with blocking and Figure 8.3/SE.1 for poles without blocking. The soil is defined in Table 8.3/SE.1 and the ground water influence in Table 8.2/SE.1.



**(ncpt) Figure 8.2/SE.1
Required length of embedding for timber poles with upper and lower stone blocking**



**(ncpt) Figure 8.3/SE.1
Required length of embedding for timber poles without stone blocking**

NOTE The line-dotted part of curve 6-8, in Figure 8. 3/SE.1 assumes back fill with coarse gravel or macadam.

(ncpt) Table 8.2/SE.1 - Increase of required embedding length for timber poles in soils with ground water

	Increase of length of embedding in metre at a ground water level of	
Foundation	**0 - 0,8 (m)**	**(0,8) - 1,6 (m)**
	under the ground level	
With blocking	0,3	0,1
Without blocking	0,2	0,1

(ncpt) Table 8.3/SE.1 - Designation for soil types in Figures 8.2.3/SE.1.1 and 8.2.3/SE.1.2

Type of soil	Excavatability	Curve No.
Gravely sandy moraine	Hard	1
Sand and stony, multi-graded gravel	Hard	2
Fine-grained sandy moraine	Normal	3
Sand and shingle	Normal	4
Silty moraine	Soft	5
Clayey gravel	Soft	6
Clayey moraine	Soft	7
Silt, clayey sand and dry sandy gravely clay	Soft	8

8.2.4 Load tests and tests on experimental models

(ncpt)

SE.1 Rock-eye bolt pull-out resistance test

The pull-out test load for verify the resistance of rock eye-bolts shall be 1,40 times the design value of the load in ultimate limit states (load combination 1) for tangent supports and 1,55 times for permanent loaded guys, e.g. angle and terminal supports.

(ncpt)

SE.2 Foundation uplift resistance test

If the resistance is determined by test the lowest obtained value shall be selected. The conditions at the tests shall be in correspondence to the actual field conditions. The application of the load shall be slowly increased. The resistance load is the lowest value of:

- the load which results in a vertical displacement of 40 mm
- 1,2 times the load which results in a displacement of 10 mm.

(ncpt)

SE.3 Loads for foundations tests

Loads for foundations tests are to be derived from the design value of the applicable support reactions, i.e. uplift force or overturning moment, multiplied with the design load / design resistance ratio of 8.2.2/SE.2 and SE.3 respectively.

8.3 Soil investigation and geotechnical data

(snc)

SE.1 Soil geotechnical characteristics

If soil investigations not have been performed the values in accordance with Table 8.3/SE.1 can be used. For other softer soils lower values should be considered.

Values for angle of internal friction, cohesion and frustum angle for overturning foundation shall be chosen in accordance with tests or practice of the utility concerned.

Other soil parameters shall be taken from handbooks covering Swedish conditions.

(snc) Table 8.3/SE.1 — Soil characteristics

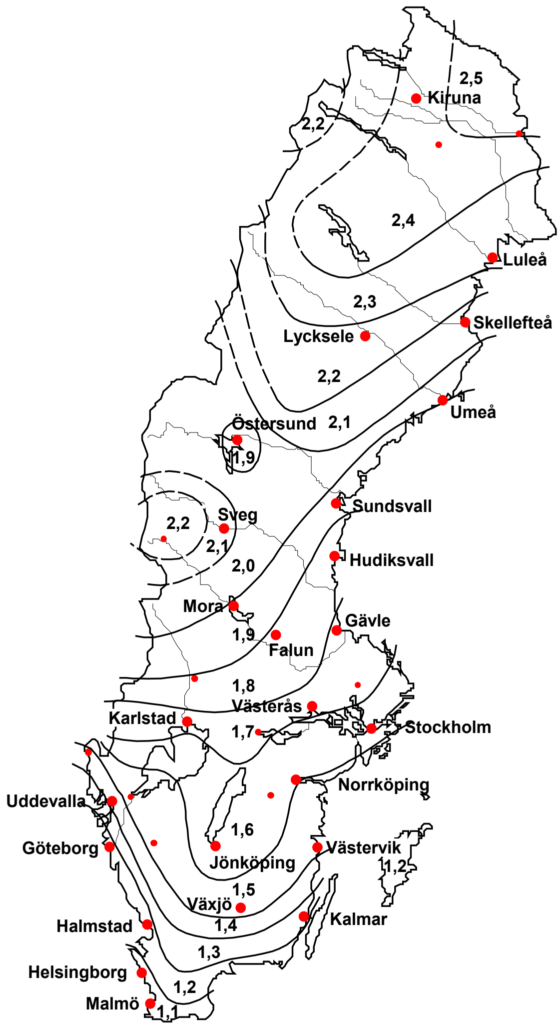
Type of soil	Specific weight force		Frustum angle for uplift foundations[1)] degree
	naturally humid kN/m^3	with buoyancy kN/m^3	
Moraine, gravel, dense sand	18	11	20
Other non-cohesive soils	16	9	20
Clay	16	6	0
Loose clay	15	5	0
1) Minimum length 150 mm for the protruding part of the pad, see Figure 8.1/SE.			

(snc)

SE.2 Frostproof depth

Foundations shall be placed on frost-proof depth. The frost-proof depth is depending on the intensity and duration of cold weather, soil type and the thickness and duration of snow. In Figure 8.4/SE the frost-proof depths are given in mineral soil, e.g. gravel, sand, moraine and clay, without a snow layer. With a snow layer the frost-proof depth is in general maximum 1,5 m for normal mineral soil. In organic soil, e.g. peat, mud and topsoil, the frost proof depth is lower than in mineral soil. The frost-proof depth in organic soil is in general about half of the depth in mineral soil.

Placing on frost-proof depth does not secure from frost heave. If possible, measures shall be taken to avoid frost heave by flank grip. Blocking of timber poles by rocks shall be avoided in frost-susceptible soil.



(ncpt) Figure 8.4/SE.1 - Map over Sweden with frost-proof depths in mineral soil with no snow layer.

8.4 Supervision of construction, monitoring and maintenance

(ncpt)

SE.1

Foundations shall be installed on a virgin soil layer. If this is not possible the soil layer under the foundation shall be carefully compacted. If possible, the soil layers around the foundation shall also be composed of virgin soil.

9 Conductors and earth-wires

9.1 Introduction

(ncpt)

SE.1

Overhead insulated cables shall be manufactured and tested according to valid Swedish Standards.

Calculation of sag and tension for overhead insulated cables shall be based on the design value of stress in serviceability limit state that is maximum 50 % of the rated tensile strength (RTS) of the complete bundled cable, messenger and tension-devices.

9.2 Aluminium based conductors

9.2.1 Characteristics and dimensions

(ncpt)

SE.1

Alteration

All aluminium conductors and aluminium conductors steel reinforced shall be in accordance with EN 50182 having dimensions in accordance with Annex F. All aluminium alloy conductors shall, for AlMgSi conductors be in accordance with SS 424 08 12 and for Al 59-conductors be in accordance with SS 424 08 14.

The material for the AlMgSi conductors shall be in accordance with SS 424 08 11 and for the Al 59-conductor in accordance with SS 424 08 13.

The minimum cross-section for aluminium based conductors shall be 31 mm^2.

The size of conductor in reinforced line and demarcation span shall be at least in accordance with Table 9.1/SE.

(ncpt) Table 9.1/SE.1 - Minimum size of aluminium based conductor in reinforced line type 1 and 2 and in demarcation span

Highest system voltage U_s kV	**Minimum conductor area**		
	Aluminium conductor steel reinforced mm^2	**All aluminium alloy conductor mm^2**	**All aluminium conductor mm^2**
≤ 55	62	99	157
(55) – 84	99	157	241
> 84[1)]	157	241	329

1) At highest system voltage greater than 84 kV may larger areas be required with consideration to radio interference disturbance.

9.2.3 Conductor service temperatures and grease performance

(ncpt)

SE.1

Unless otherwise provided, the following applies:

- the maximum service temperature at normal line loading shall be 70 °C
- the maximum short duration temperature for some day per year at different line loading above the normal level shall be 100 °C
- the maximum temperature due to specified power system fault shall be 200 °C.

9.2.5 Corrosion protection

(ncpt)

SE.1

The grease shall not affect the material of the conductor. The required penetrability is 325 and the temperature range is: Θ_1 = -20 °C, Θ_2 = 225 °C.

9.2.6 Test requirements

(ncpt)

SE.1

The AlMgSi conductors shall be tested in accordance with SS 424 08 12.

The Al 59 conductors shall be tested in accordance with SS 424 08 14.

9.3 Steel based conductors

9.3.1 Characteristics and dimensions

(ncpt)

SE.1

The minimum cross-section for the steel conductors and earth wires shall be 25 mm^2.

The size of conductor in reinforced line and demarcation span shall be at least in accordance with Table 9.2/SE.1.

(ncpt) Table 9.2/SE.1 - Minimum size of steel conductor in reinforced line and demarcation span

Highest system voltage U_s kV	Minimum conductor area mm^2
1 ≤ 55	33
(55) - 84	33
> 84[1)]	52[2)]
1) At highest system voltage greater than 84 kV may greater areas be required with consideration to radio interference disturbance. 2) In separation structure may 33 mm^2 be used	

9.3.3 Conductor service temperatures and grease characteristics

(ncpt)

SE.1

The maximum temperature due to specified power system fault shall be 300 °C.

9.3.4 Mechanical requirements

(ncpt)

SE.1

See 9.6.4/SE.1.

9.4 Copper based conductors

(ncpt)

SE.1 Characteristics and dimensions

The minimum cross-section for the copper conductors shall be 16 mm^2.

The size of conductor in reinforced line and demarcation span shall be at least in accordance with Table 9.3/SE.1.

(ncpt) Table 9.3/SE.1 - Minimum size of copper conductor in reinforced lines and demarcation span

Highest system voltage U_s kV	Minimum conductor area mm^2
≤ 24	25
(24)-55	35
(55) – 84	50
> 84[1)]	120
1) At highest system voltage greater than 84 kV may greater areas be required with consideration to radio interference disturbance.	

(ncpt)

SE.2 Conductor service temperatures

The maximum service temperature at normal line loading shall be 50 °C.

The maximum short duration temperature for some day per year at different line loading above the normal level shall be 70 °C.

The maximum temperature due to specified power system fault shall be 150 °C.

(ncpt)

SE.3 Mechanical requirements

See 9.6.4/SE.1.

9.5 Conductors and ground wires containing optical fibre telecommunication circuits

9.5.1 Characteristics and dimensions

(ncpt)

SE.1

The minimum cross-section shall conform to the requirements of the corresponding conductor material specified in Subclauses 9.2-9.4 and 9.2-9.4/SE unless otherwise specified by the client.

9.5.3 Conductor service temperatures

(ncpt)

SE.1

The maximum service temperature at normal line loading shall be 70 °C.

The maximum short duration temperature for some day per year at different line loading above the normal level shall be 100 °C.

The maximum temperature due to specified power system fault shall be 200 °C.

9.5.4 Mechanical requirements

(ncpt)

SE.1

See 9.6.4/SE.1.1, Design value of stress for aluminium based conductors.

9.6 General requirements

9.6.2 Partial factor for conductor

(ncpt)

SE.1

Partial factor for conductors see 9.6.4/SE.1.

9.6.4 Sag - tension calculations

(ncpt)

SE.1 Conductors

Conductors shall be tensioned in such an arrangement that the tension stress σ_0 in the bare conductor at 0 °C and no wind will be equal in all spans between two termination points. The tension stress σ_0 shall be selected in the way that the stress in the conductor, at uniform ice load and no wind at 0 °C in accordance with 4.5.2/SE.1.2 or SE.1.4, does not exceed the stress below.

In addition, the tension at 0 °C and no wind or ice shall be selected with respect to the danger of fatigue breakage in the conductor due to conductor vibrations. No general rules for the conductor tensioning can be given as the risk of dangerous vibration is not only depending on the conductor tension, but also on the character of the terrain, the wind, the performance of the conductor attachments, span length and the vibration damper system.

The design value of stress f_d for conductors in load combination 2, according to Table 4.7/SE.1, shall be less than or equal to:

- Copper conductors: 320 MPa
- All aluminium, all aluminium alloy, aluminium conductor steel reinforced or steel conductors: 55 % of the RTS (rated tensile strength) in accordance with relevant conductor standard.

At calculation for conductors of all aluminium, all aluminium alloy, aluminium conductor steel reinforced, copper or steel the values given in Table 9.4/SE.1 shall be used. Alternatively, the modulus of elasticity obtained from tests in accordance with SS-EN 50182 annex C and the creep elongation obtained from tests in accordance with SS-EN 61395 shall be used. This creep test shall be performed at a temperature between +21 to +25 °C during a test period of 1500 h and with a stress equivalent to 40 % of the conductor’s ultimate tensile strength.

For conductors which are not to be found in Table 9.4/SE.1 the stress strain characteristic and elongation due to creep shall be established. The stress strain characteristic shall consider the initial nonlinear properties as well as the differences between initial and final properties. The amount of creep shall be what can be expected to occur after 10 years of service. Tests in accordance with SS-EN 50182 may be used in order to establish the stress strain characteristics. Tests in accordance with SS-EN 61395 may be used to in order to establish the creep value.

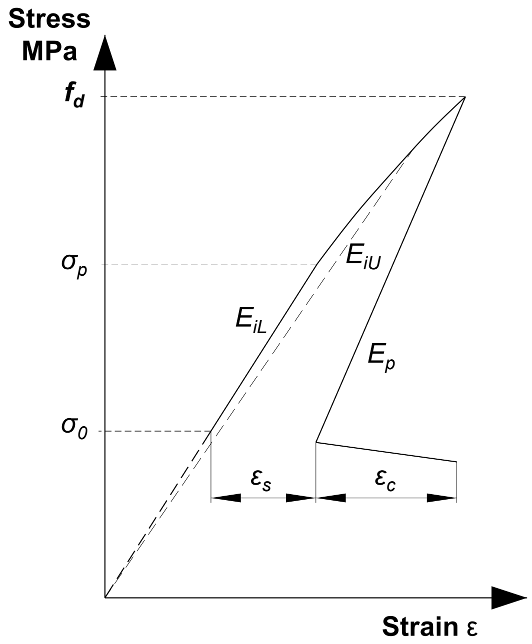
(ncpt) Table 9.4/SE.1 - Modulus of elasticity, elongation due to creep and expansion coefficient for conductors

Conductor type and stranding	Modulus of elasticity Initial, (before ice load) E_{iL}	Modulus of elasticity Final, (after ice load) E_p	Highest stress σ_p at which given value of E_{iL} is valid	Permanent elongation due to creep Factor x	Permanent elongation due to creep ε_c	Permanent elongation due to creep correspond to a rise temperature	Expansion coefficient
	MPa	MPa	MPa		‰	°C	10^{-6}/°C
All aluminium							
7 wires	47 000	61 000	60	280	0,8	35	23
19 wires	45 000	60 000	60	280	0,8	35	23
37 wires	43 000	58 000	60	280	0,8	35	23
61 wires	40 000	56 000	60	280	0,8	35	23
All aluminium alloy							
7 wires	65 000	67 000	100	140	0,4	17	23
19 wires	61 000	64 000	100	140	0,4	17	23
37 wires	57 000	62 000	100	140	0,4	17	23
61 wires	53 000	60 000	100	140	0,4	17	23
Aluminium conductor steel reinforced							
1 + 6 wires	59 000	80 000	135	145	0,3	16	19
7 + 12 wires	91 000	105 000	170	75	0,2	13	15
7 + 26 wires	60 000	76 000	120	160	0,4	21	19
7 + 32 wires	74 000	83 000	150	80	0,3	17	18
7 + 42 wires	47 000	60 000	100	145	0,5	24	21
7 + 54 wires	52 000	72 000	120	90	0,4	21	19
19 + 54 wires	51 000	71 000	120	85	0,4	21	19
Copper, All stranding							
	100 000	116 000	200	166	0	0	17
Steel, All stranding							
600 MPa	163 000	180 000	330	-	0	0	11
1400 MPa	180 000	180 000	770	-	0	0	11

NOTE The modulus of elasticity for conductors of all aluminium, all aluminium alloys and aluminium conductor steel reinforced will vary at loading within the entire stress-strain region. An increased load gives a permanent elongation ε_s in the conductor, see Figure 9.1/SE. This elongation depends partly on the material characteristics of aluminium and theirs alloys and partly on the settlement of the wires in the conductor. The settlement will also occur in conductors of copper or mild, 600 MPa, steel.

The elongation has been taken into consideration at the determination of the modulus of elasticity *Ei*.

In spite of above-mentioned variation in modulus of elasticity the conductors can be calculated with sufficient accuracy by using a constant value of E_i, in Table 9.4/SE.1 designated E_{iL}.



(ncpt) Figure 9.1/SE.1 - Stress – strain

The initial modulus of elasticity E_{iL} in accordance with Table 9.4/SE.1 shall be used at stress levels equal to or lower than $\boldsymbol{\sigma_p}$ given in Table 9.4/SE.1.

The modulus of elasticity E_{iU}, determined in accordance with the formula

$$E_{iU} = E_{iL} - x(\sigma - \sigma_p)$$

shall be used at stress levels higher than σ_p given in Table 9.4/SE.1. The modulus of elasticity E_{iL} and the factor x shall be taken from Table 9.4/SE.1.

NOTE In the formula σ refer to the highest stress in MPa without any regard to creep.

The final modulus of elasticity after ice load on the conductor, E_p, shall be assumed to have a constant value in accordance with Table 9.4/SE.1. This value shall be used at stress relieving (unloading) as well at reloading.

The increased conductor sag due to creep shall be calculated by using the value of $\boldsymbol{\varepsilon_c}$ or by using the corresponding rise temperature in accordance with Table 9.4/SE.1.

NOTE Conductors, containing aluminium or aluminium alloy, will by time gain a permanent elongation ε_c due to creep in the metal, see Figure 9.1/SE.1. The creep will increase by increased stress and temperature respectively. At constant stress and temperature the creep proceed with decreased velocity over time.

The conductor sag shall, since the creep continue successively during a long time, be calculated for the following two load cases:

- Initial stage and before conductor creep
- Final stage and after conductor creep

The clearance distances and acting loads on the supports shall be calculated at the most unfavourable values of sags and loads.

(ncpt)

SE.2 Overhead insulated cables

Cables shall be tensioned in such an arrangement that the tension stress σ_0 in the messenger or the cable at 0 °C and no wind will be equal in all spans between two termination points. The everyday tension stress σ_0 shall be selected in such a way that the stress in the messenger or the cable does not exceed the stress in accordance with 9.1/SE1 at load cases according to 4.12/SE.5 for load combination 2.

In addition, the tension at 0 °C and no wind or ice shall be so selected that the sag in the equivalent span will be minimum 2 % of the span length.

9.8 Selection, delivery and installation of conductors

(ncpt)

SE.1 Reinforced line

Re-use of conductor is not allowed in reinforced line or demarcation span without carefully examination of the used conductor. All damaged parts shall be scraped.

Joint shall not be installed in demarcation span. Compressed dead end clamp with jumper terminal is equal with joint in this case. Joint should be avoided in the crossing and the spans in the adjacent of the crossing span. Joint in such span shall be protected for oxidising and corrosion which otherwise will reduce their electrical and mechanical properties.

(ncpt)

SE.2 Crossing

Conductor shall be attached to the insulator/ insulator set in that way no danger situation will arise in the crossing in that case a conductor failure will occur in the vicinity outside the terminal support or demarcation span. Furthermore shall no damage occur at the insulator or the fitting, i.e. conductor clamps. These requirements shall be fulfilled at the highest load in the conductor for which the support is designed. If parallel insulators are used the requirement is valid for when only one insulator is functioning.

Joint in crossing with greater traffic roads and the adjacent span should in addition be reinforced both electrically and mechanically. Dead end clamp with through conductor is equal to such joint.

10 Insulators

10.2 Standard electrical requirements

(ncpt)

SE.1

(ncpt) Table 10.2/SE.1 - Standard electrical requirements

Voltage range	1 kV ≤ U_s ≤ 72 kV				
Insulator type	Cap and pin	Long rod	Composite	Line post	Pin
Wet power frequency withstand voltage	X	X	X	X	X
Dry lightning impulse withstand voltage	X	X	X	X	X
Puncture withstand voltage	X	-	-	-	X

(ncpt) Table 10.2/SE.2 - Standard electrical requirements

Voltage range	72,5 kV < U_s ≤ 245 kV			
Insulator type	Cap and pin	Long rod	Composite	Line post
Wet power frequency withstand voltage	X	X	X	X
Dry lightning impulse withstand voltage	X	X	X	X
Switching impulse withstand voltage	X	X	X	X
Puncture withstand voltage	X	-	-	-

(ncpt) Table 10.2/SE.3 - Standard electrical requirements

Voltage range	U_s > 245 kV		
Insulator type	Cap and pin	Long rod	Composite
Dry lightning impulse withstand voltage	X	X	X
Switching impulse withstand voltage	X	X	X
Puncture withstand voltage	X	-	-

Guy insulators used in systems with earth fault current below 500 A shall be capable to withstand a wet power frequency withstand voltage equal to the highest system voltage of the line in which the guy insulator is installed.

10.7 Mechanical requirements

(ncpt)

SE.1 Dimensioning load

The design value of actions E_d at load combination 2, at load cases in accordance with Table 4.7/SE.1, shall be less than or equal to the design resistance R_d for insulators.

$$R_d = \frac{F_{uk}}{\gamma_M}$$

where

F_{uk} is:

- Specified mechanical failing load (MFL) for string insulator units, for guy insulators and for bobbin insulators
- Specified mechanical load (SML) for composite string insulator units
- Specified cantilever failing load for pin and line post insulators

γ_M is:

- Porcelain or glass string insulator unit $\gamma_M = 2{,}5$
- Composite string insulator unit and guy insulator $\gamma_M = 2{,}5$
- Pin insulator, line post insulator and bobbin insulator $\gamma_M = 2{,}0$

10.10 Characteristics and dimensions of insulators

(ncpt)
SE.1

Pin insulators shall be according to SS 424 05 02.

Guy wire insulator of porcelain or composite material shall meet electrical and mechanical requirements according to SS 424 05 31. Test shall be performed according to relevant parts of EN 60383-1, EN 60383-2 and IEC 61109.

10.16 Selection, delivery and installation of insulators

(ncpt)
SE.1 Crossing

Transposition insulator sets are not allowed in crossing spans.

(ncpt)
SE.2 Reinforced line and crossing with reinforced span

Pin insulator is not allowed in reinforced lines type 1 and 2 and in crossing with reinforced span.

Insulator in crossing support shall fulfil the following requirements:

- Line-post insulator shall be arranged in that way that the insulator, at conductor failure, will not bend in the attachment point more than that temporary operational service can be maintained.
- Conductors that come loose from bobbin insulator shall be kept in the insulator attachment.
- Insulator set consisting of two or more insulator strings shall be arranged in that way the strength will not be considerable reduced if failure will occur in one string.

11 Hardware

11.2 Electrical requirements

11.2.2 Requirement applicable to current carrying fittings

(ncpt)

SE.1

Conductor joint, tension clamp and jumper clamp shall have greater current carrying capability than the conductor itself. These requirements shall also be fulfilled after a short circuit current equal to the rated short circuit current for the conductor but for maximum 50 kA-1 second.

The voltage drop across the current carrying connector shall not be greater than 55 % of the voltage drop across equivalent length of conductor.

11.6 Mechanical requirements

(ncpt)

SE.1

(ncpt)

SE.1.1 Dimensioning load

The design value of actions E_d shall be in accordance with Table 4.7/SE.1, load combination 1.

The stresses shall not exceed the design value of stress f_d for the material in accordance with Clause 7 and 7/SE.

Alternatively the mechanical strength may be determined by test at which the following two criteria shall be fulfilled:

- Permanent deformation by tension-, compression-, bending- and shearing load shall not occur in fittings made of steel or aluminium alloy at a load corresponding to 1,10 times R_d.
- Failing load F_u shall exceed $F_k = R_d \cdot \gamma_M$ for fittings tested statistical in accordance with IEC 60383-1.

where

R_d = The design value of resistance in load combination 2

γ_M = shall be in accordance with 10.7/SE.1. At test on separate samples γ_M shall be increased by 10 %

(ncpt)

SE.2.1 Mechanical failing load for joint in bare or covered conductor, tension clamp and jumper clamp

The mechanical failing load shall be at least 90 % of the failing load, obtained at test, of the conductor.

(ncpt)

SE.2.2 Mechanical failing load for joint in overhead insulated cable

The mechanical failing load of a joint in a conductive wire or in the supporting wire shall be at least 90 % of the failing load of the complete cable, conductive wire or supporting wire.

Joint is not allowed in crossings.

(ncpt)

SE.2.3 Load limiting device for overhead insulated cable systems

Load limiting devices can be installed in supports. Such device shall be so designed that:

1) It will fail before other components of the line will fail when the line is subject to excessive loads resulting from falling trees, ice loads or similar.
2) It will not fail for loads specified in this standard.

Load limiting devices shall not be installed in supports at crossings.

The reliability can be reduced if load limiting devices are installed in supports where joints between aerial cable and other cable (underground cable) are located.

11.7 Durability requirements

(ncpt)

SE.1

Hot dip galvanising of insulator fittings shall be in accordance with SS-EN ISO 1461.

11.14 Selection, delivery and installation of fittings

(ncpt)

SE.1

Normative amendment

(ncpt)

SE.1.1 Protective measures for class A transmission lines

Transmission lines shall withstand the short circuit current at the cut-off time as is valid for the line. The short circuit reliability will be achieved if insulator, fittings and conductor either will withstand or will be protected for damage. This will be fulfilled by the following measures:

- Insulator shall have sufficient puncture capability
- Fittings shall have sufficient ability to carry the current
- Conductor clamp shall have sufficient ability to carry the current
- Installation of arcing protection devices as shall catch and guide the arc away from the insulator string, fittings and conductor
- Reduction of the cut-off time

(ncpt)

SE.1.2 Suspension insulator sets

Arcing protection devices give sufficient protection of insulator string and the device at the energised side is considered to give sufficient protection of the conductor in the vicinity of the conductor clamp

(ncpt)

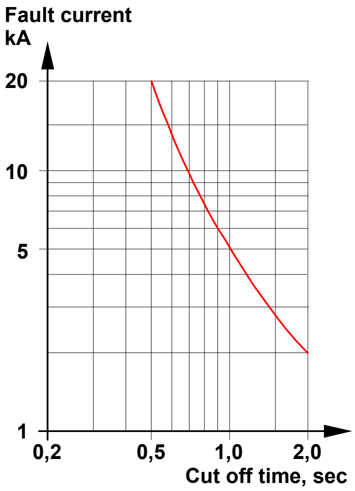
SE.1.3 Tension and transposition insulator sets

Arcing protection devices give sufficient protection of insulator string.

(ncpt)

SE.1.4 Line-post insulators

Line-post insulators in accordance with SS 424 05 21 is considered to withstand power arc flashover at fault currents and cut-off times given in Figure 11.1/SE.1. One or the other of top-clamp, hand-tie in accordance with SS 424 12 50 or preformed tie in accordance with SS 424 12 51 is considered to give enough protection to the conductor within the same conditions.



(ncpt) Figure 11.1/SE.1 - Graph of safe border line for line-post insulators

(A-dev)

SE.1.5 Line with covered conductor

To prevent covered conductor from being burnt off at a lightning stroke to the line, arcing protection shall be installed in

- reinforced lines of type 1 and 2.
- crossing with other lines and traffic routes.

Arcing protection at crossings shall include the two crossing poles and the adjacent poles that can affect the safety of the crossing.

(ncpt)

SE.2 Reinforced lines of type 1 and 2

The requirements of 11.14/SE.1.1 apply for reinforced line type 1 and 2 lines.

(ncpt)

SE.3 Joint, tension clamp and jumper clamp

Conductor joint, tension clamp and jumper clamp shall be designed in such a way that the conductor will be unaffected.

Solder joint shall not be used.

12 Quality assurance, Checks and taking-over

12.2 Checks and taking-over

(A-dev)

SE.1

A high voltage transmission line within a system with earth fault current above 500 A must be licensed by the Swedish National Electrical Safety Board in accordance with SFS 2017:218 § 7 before it will be put into service.

Annex E Electrical requirements

E.2 Insulation co-ordination

(ncpt)

SE.1

Representative overvoltages shall be in accordance with 5.4/SE.1

Annex G Earthing systems

G.2 Material constants

(ncpt)

SE.1 Minimum dimension of earth electrode materials

Minimum dimensions and cross-sections of earth electrodes from different materials shall be in accordance with 6.2.1/SE

Annex J Lattice steel towers

J.5 Design resistance of bolted connections

(ncpt)

SE.1

The reduction factors in Table J.3 shall be taken as follows:

$\eta_1 = 1,0$

$\eta_2 = 0,9$

$\eta_3 = 0,9$

$\eta_4 = 1,0$

$\eta_5 = 1,0$

For bolts where the threaded portion affects the bearing area, the bolt diameter d for the calculation of the bearing resistance shall be

$$d = \sqrt{\frac{4 \cdot A_S}{\pi}} .$$

Annex K Steel poles

K.6 Design of holding-down bolts - Table K.2

(ncpt)

SE.1

Partial safety factor on resistance of holding down bolts $\gamma_{Mb} = 1,2$

The tension and compression forces shall be combined with shear forces in the bolt according to EN 1993-1-8.

Annex M Geotechnical and structural design of foundations

M.1 Typical values of the geotechnical parameters of soils and rocks

(ncpt)

SE.1

Geotechnical parameters shall be chosen in accordance with 8.3/SE.1.

M.2.3 Calculation of R_S

(ncpt)

SE.1

The formula for calculation of R_{slab} is to be amended as follows:

$$R_{slab} = P \times h \times \left[\frac{c_s}{2} + \frac{1}{2} \times K_0 \times \gamma \times (2 \times D - h) \times \tan(\phi_s) \right]$$

(ncpt)

SE.2

The formula for calculation of R_{slab} only applies where the sides of the concrete slab is directly cast to virgin soil. Where this is not the case the following formula applies:

$$R_{slab2} = P \times h \times \frac{1}{2} \times K_a \times \gamma \times (2 \times D - h) \times \tan(\phi_s)$$

(ncpt)

SE.3

The following formula for calculation of the earth pressure coefficient at rest is to be applied:

$$K_0 = 1 - \sin(\phi)$$

M.2.4 Analytical evaluation of R_d

(ncpt)

SE.1

R_d is to be evaluated in accordance with design approach 2 with the following partial factors.

Foundations not subject to permanent uplift loads γ_R = 1,1

Foundations subject to permanent uplift loads γ_R = 1,25

These partial factors apply both for long term evaluation and short term evaluation.