Overhead transmission lines
Bolted connectors

Introduction
This document in English shall be regarded as a translation of the corresponding
guidelines in Swedish. The aim of the translation is to provide support to foreign
manufacturers. The wording in Swedish and the interpretation thereof shall govern
contract and legal relations between the parties of the purchasing process.

These guidelines describe the requirements on bolted connectors with limited tensile
strength for steel reinforced aluminium conductors, aluminium conductors and
aluminium alloy conductors in accordance with TR 05-04E for overhead transmission
lines and cover design and inspection. The guidelines intend to guarantee satisfactory
performance of bolted connectors during the lifetime of the overhead line and shall be
used at purchasing of bolted connectors.
## Revisions

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15.1 References

Note that standards, regulations etc. which are referred to in these guidelines are subject to continuous change and can be withdrawn, revised or replaced. It is the obligation that the contractor immediately will inform the client of such changes.

SS ISO 2178 Non-magnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method

ISO 4015 Hexagon head bolts -- Product grade B – Reduced shank (shank diameter approximately equal to pitch diameter)

SS 1964 Threaded blind holes - ISO metric screw threads - Coarse pitch

SS 2173 Diameters of spot facings, counter-bores and countersinks - Screws and nuts with ISO metric screw threads and tapping screws

SS-EN 9001 Quality management systems - Requirements

SS-EN 10002-1 Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature

SS-EN 61284 Overhead lines – Requirements and tests for fittings

SS-EN ISO 887 Plain washers for metric bolts, screws and nuts for general purposes - General plan (ISO 887:2000)


SS-EN ISO 7089 Plain washers - Normal series - Product grade A

SS-EN ISO 3506-1 Mechanical properties of corrosion-resistant stainless-steel fasteners - Part 1: Bolts, screws and studs

SS-EN ISO 3506-2 Mechanical properties of corrosion-resistant stainless-steel fasteners -- Part 2: Nuts

SS-EN ISO 4014 Hexagon head bolts - Product grades A and B (ISO 4014:1999)

SS-EN ISO 4032 Hexagon nuts, style 1 - Product grades A and B


SS-ISO 272 Fasteners -- Hexagon products -- Widths across flats

SS-ISO 1101 Technical drawings - Geometrical tolerancing - Tolerancing of form, orientation, location and run-out -
These guidelines describe the requirements on bolted connectors with limited tensile strength for steel reinforced aluminium conductors, aluminium conductors and aluminium alloy conductors in accordance with TR 05-04E for overhead transmission lines and cover design and inspection. The guidelines intend to guarantee satisfactory performance of bolted connectors during lifetime of the overhead line and shall be used at purchasing of bolted connectors.

SS-EN 61284 has been taken into consideration at the establishment of these technical guidelines. The standards requirements has been studied and analysed at which it has been found that they do not give a sufficient level against deterioration in the current carrying capacity during the lifetime of the overhead line which have given rise to that the technical guidelines have got this shape.

15.3 Definitions

Technical terms and definitions used in these guidelines.

**Body**
That part of the bolted connector in which the current is transferred between the conductors attached to the connector.

**Highest voltage for equipment**
The highest value of phase-to-phase voltage for which the equipment is designed.

**Corona extinction voltage**
The voltage where no corona is visible when the voltage is reduced from a level with visible corona.

**Fault current**
The greatest short duration current which is caused by either a short-circuit (I_k) or an earth fault (3I_o)
**Keeper**
That part of the bolted connector that clamps the conductor to the body.

## 15.4 Description

### 15.4.1 Bolted connector
Device, comprising several parts for jointing two conductors in order to provide electrical contact between two conductors, where the contact is acquired by bolt connection. Bolted connector is intended for low tension forces in the connected conductors.

- **15.4.1.1 Parallel groove clamp**
  Bolted connector to create connection between wrap-over conductors. See Figure 1.

- **15.4.1.2 T-clamp**
  Bolted connector to create connection between main conductor and branch conductor. See Figure 2.

## 15.5 Requirements

### 15.5.1 General
Bolted connectors shall be able to withstand the mechanical stresses which can occur during transport, handling and installation at temperatures as low as –40° C, in addition to the mechanical stresses which can occur during the lifetime of the overhead line at temperatures from -50° to +100° C.

### 15.5.2 Material

- **15.5.2.1 Aluminium**
  Connectors shall be manufactured from aluminium alloy. The alloy, which must not contain more than 0,1 % Cu, shall not be liable to stress, cracking or layer corrosion. Cast and wrought aluminium shall fulfil the requirements relating to tensile strength, hardness and resistivity as specified in Table 3.

- **15.5.2.2 Steel**
  Bolts and nuts shall be made of stainless steel and fulfil the requirements for A2-80 or A4-80 in accordance with and SS-EN ISO 3506-1 and SS-EN ISO 3506-2. Washers and thread inserts shall be made of stainless steel, and shall have at least the same resistance to corrosion as steel grade A2 in accordance with SS-EN ISO 3506-1.

### 15.5.3 Design

- **15.5.3.1 General**
  Connectors shall be so designed that water collection is eliminated. If this is not possible, they shall have drainage holes with a minimum diameter of 6 mm. Current-carrying parts of the connectors shall be cast or forged in one piece. Connectors intended for connection of parallel stranded conductors shall consist of two current-carrying parts. Bolts shall be positioned between the conductor grooves. The number of bolts shall be as specified in Table 1.
Connectors with keepers shall have the number of keepers as specified in Table 2. There shall be two bolts for each keeper. Bolts shall be equally positioned on each side of the conductor groove.

15.5.3.2 Conductor grooves
The connectors shall have a conductor groove for each conductor. Each groove shall be adapted to the conductors in accordance with table 4-8 and SvK TR 05-04E in such way that it is possible to install that any of the conductors with the same external diameter without causing permanent deformation of the connectors. Conductor groove lengths shall be as specified in Table 1 and 2.

Conductor grooves shall be so designed that they do not reduce the strength of the conductors.

The edges of conductor grooves, G in accordance with Figures 3 to 5, shall be rounded with a minimum radius of 1 mm.

The ends of conductor grooves, K in accordance with Figures 3 to 5, shall be rounded, with a minimum radius of 2 mm.

Conductor grooves for stranded conductors terminating in the connectors shall be provided with a lashing notch for the end of the stranded conductor. This notch shall have a minimum length of 8 mm and a minimum depth of 2 mm.

15.5.3.3 Contact surfaces
Current-carrying contact surfaces of cast aluminium shall be machined and free from casting skin. Current-carrying contact surfaces of wrought aluminium need not necessarily be machined. Current-carrying contact surfaces in conductor grooves for stranded conductors shall have a surface smoothness R not less than N8 in accordance with SS-EN ISO 1302. The contact surfaces may be transversely furrowed but the depth of such furrows shall not exceed 1 mm. Contact surfaces in keeper shall be smooth.

Parallel groove clamps
Parallel groove clamps shall have current-carrying contact surfaces in accordance with Tables 1. Current-carrying contact surfaces in parallel groove clamps, see Figure 3, is calculated in accordance with:

\[ A = (\pi * D - 2 * (D - 2 * S) - 4 * G) * (L - 2 * K) \]

A = Contact surface of the keepers
D = Conductor diameter in accordance with table 4-8 and SvK TR 05-04E
S = Nominal depth of conductor groove
G = Nominal rounding of edges of conductor groove
L = Nominal length of conductor groove
K = Nominal rounding of ends of conductor groove
U = Total area of notches which reduce the contact surface in conductor groove in the keepers for each conductor

Note: Nominal size in accordance with this figure shall be the mean value of high and low limits.

Clamps with keepers
Clamps with keepers shall have current-carrying contact surfaces in accordance with Tables 2. Current-carrying contact surfaces in clamps with keepers, see Figure 4, is calculated in accordance with:

\[ A = (0.5 * \pi * D - 2 * (0.5 * D - S) - 2 * G) * (L - 2 * K) \]
A = Current-carrying contact surface in the conductor groove
D = Conductor diameter in accordance with table 4-8 and SvK TR 05-04E
S = Nominal depth of conductor groove
G = Nominal rounding of edges of conductor groove
L = Nominal length of conductor groove
K = Nominal rounding of ends of conductor groove
U = Total area of notches which reduce the contact surface in conductor groove

Note: Nominal size in accordance with this figure shall be the mean value of high and low limits.

**Keepers**
Keepers shall have contact surfaces in accordance with Tables 2. Contact surfaces in keepers, see Figure 5, is calculated in accordance with:

\[
B = (0.5 \times \pi \times D - 2 \times (0.5 \times D - T) - 2 \times G) \times (M - 2 \times K) \times N
\]

B = Contact surface of the keepers
D = Conductor diameter in accordance with table 4-8 and SvK TR 05-04E
T = Nominal depth of conductor groove
G = Nominal rounding of edges of conductor groove
M = Nominal length of each keeper
K = Nominal rounding of ends of conductor groove
N = Number of keepers for each conductor
U = Total area of notches which reduce the contact surface in conductor groove in the keepers for each conductor

Note: Nominal size in accordance with this figure shall be the mean value of high and low limits.

**15.5.3.4 Bolts and nuts**
Bolts and nuts should be captive in the clamps, in order to simplify hot line working. The connectors shall be equipped with the number of bolts as specified in Table 1 and 2. Bolt threads shall be M10 or M12.

Bolts, which are tightened during installation, shall have bolt heads in accordance with ISO 4014 or ISO 4015. Nuts, which are tightened during installation, shall be in accordance with ISO 4032. The width across flats shall be in accordance with SS-ISO 272. Other designs of bolt heads and nuts shall be approved by Svenska Kraftnät. The bolts shall be so long that they end outside the nut threads in the installed position.

Countersinks for tightening tools shall be in accordance with SS 2173.

**15.5.3.5 Washers**
Flat washers shall be fitted beneath bolts and nuts which are tightened during installation. The washers shall be in accordance with SS-EN ISO 887 and SS-EN ISO 7089.

**15.5.3.6 Threaded holes**
Threaded blind holes shall have sufficient depth to ensure full tightening of bolts without bottoming. Threaded holes in cast aluminium according to Table 3 shall be fitted with thread inserts. Threaded holes in forged aluminium according to Table 3 may be cut directly in the aluminium and shall be in accordance with SS 1964.
15.5.4 Mechanical requirements

15.5.4.1 Tightening torque
Tightening torques for bolts and nuts shall be 45 Nm for M10 and 75 Nm for M12.

15.5.4.2 Threaded hols
Threaded holes shall have at least the same strength as nuts in quality A2-80 according to SS-EN ISO 3506-2.

15.5.4.3 Washers
Washers shall have a hardness of minimum HV 200 at test in accordance with SS-EN ISO 6507-1.

15.5.4.4 Contact force
The mean value for the pre-stressing forces in the bolts shall for each separate conductor connection be 25 kN for M10 and 35 kN for M12 with respect to the difference in thermal expansion between aluminium and stainless steel at the tightening torque in accordance with Clause 15.5.4.1.
The connectors shall provide the contact forces specified in Table 1 and 2. Contact forces are defined in Figure 6 and 7.

15.5.4.5 Deformation
Permanent deformation shall not occur in current carrying parts or creepers at 110% of the tightening torques in accordance with Clause 15.5.4.1.

15.5.5 Electrical requirements

15.5.5.1 General
Permanent deformation, cracks or failure shall not occur in current carrying parts due to clashing of conductors at fault current. The connector surface shall not be treated in order to increase the emission coefficient.

15.5.5.2 Continuous current
The bolted connector shall be capable to carry the continuous currents in accordance with table 4-8 and SvK TR 5-04E without reaching a temperature higher than the weakest conductor connected by the connector.

15.5.5.3 Corona
Connectors shall have no visible corona at the test voltage defined by:

\[ \text{Test voltage} = \frac{U_m}{\sqrt{3}} \times 1.1 \]

Where \( U_m \) is 245 kV respectively 420 kV.

15.5.5.4 Resistance
Bolted connector for phase conductor shall have a resistance (R1) of maximum 55% of the resistance value for the corresponding length of conductor, measured from conductor to conductor in the vicinity of the connector. See Figures 8 and 9. Furthermore, the resistance R2 according to Figure 9 shall be measured.

15.6 Type test

15.6.1 General
Type inspection relates to tests as described in Clauses 15.6.2 – 15.6.8, intended to confirm and document that the connectors tendered fulfil the requirements of this technical guideline.
Tests shall be carried out and paid for by the manufacturer. By agreement with the client, tests may be carried out by the manufacturer. Tests may be carried out indoors and at room temperature.

Unless otherwise prescribed, test shall be performed in accordance with Clause 15.6.2-15.6.8, on at least three (3) samples. After agreement with Svenska Kraftnät this number may be reduced. Tests shall be performed in such a manner that neither the test procedures nor the test equipment affect the result. By agreement with the client, connectors consisting of parts which have already been tested may be partly or entirely approved without further testing.

15.6.2 Dimensions
This test intends to check that the connectors fulfil the requirements in accordance with Clause 15.5.3 and that they are also in accordance with the manufacturers drawing regarding measurements.

15.6.3 Contact force
This test is intended to document that the connectors fulfil the requirements of Clause 15.5.4.4 in respect of contact forces.

Contact forces shall be measured for three successive installations. The contact force may be measured by means of a load cell.

For connectors consisting of two current carrying parts the contact force may be measured for one bolt and one conductor groove at a time, see Figure 6. When carrying out the tests, a steel-bar of the appropriate size may be fitted in the other conductor groove. When measuring contact forces for one bolt and one conductor groove at a time, the total contact force for each conductor groove will be given by the sum of the individual measured forces.

For connectors with keepers in accordance with Figure 7, it is permissible for the contact forces to be measured for one keeper at a time. The total contact force for each conductor groove will then be given by the sum of the individual measured forces.

The contact force for conductor groove must exceed the contact forces specified in Tables 1 and 2 in all three installations. If the connectors are equipped with bigger bolts then given in those tables a corresponding higher contact forces shall have been reached.

15.6.4 Deformation
This test is intended to document that the connectors fulfil the requirements of Clause 15.5.4.4 in respect of permanent deformations.

Connectors shall be installed and removed three times successively at AL1 conductors in accordance with table 4-8 and SvK TR 05-04E. New conductors shall be used for each successive installation.

Deformation in the connectors shall be measured during testing. This can be done by means of strain gauges.

After completion of tests the residual elongation shall not exceed 0.15 % in any part of the connectors. Moderate impressions by the conductors in conductor grooves will not be regarded as permanent deformation. Threaded parts shall not have sheared. After the three installations/dismantling the contact forces shall be measured in accordance with Clause 15.6.3.

15.6.5 Threaded holes
This test is intended to document that threaded holes in aluminium parts with and without threaded inserts fulfil the requirements of Clause 15.5.4.2.
The bolts shall be inserted 15 mm in the threaded holes for M10 and 18 mm for M12.

The bolts shall be tension loaded in the axial direction of the bolt with the test force of 45 kN for M10 and 67 kN for M12.

After completion of the test no failure of the threaded holes shall have arisen. The bolts shall be easy to turn by the fingers.

15.6.6 Washers
This test is intended to document that the hardness of the washers fulfil the requirements of Clause 15.5.4.3.

The test shall be in accordance with SS-EN ISO 6507-1.

15.6.7 Corona
The intention of this test is to establish the corona extinction voltage and is to be performed in a fully darkened room. During the corona test the use of either field-glass with a minimum optical performance of 7x50 or an image intensifier with light amplification greater than 40000 in accordance with SS-EN 61284 is recommended. The connector shall be installed on conductors in accordance with SvK TR 05-04E. A minimum clearance of 4 metres from live objects to earth shall be maintained. The connector shall be subjected to an alternating current with a frequency of 50 Hz. The corona extinction voltage shall exceed the test voltage of Clause 15.5.5.3. It should be recorded by colour photographs, one with visible corona and one at the corona extinction voltage level. The voltage levels should be indicated on the photographs. The test shall be performed in accordance with SS-EN 61284 where applicable.

15.6.8 Resistance
The test is intended to verify that the connectors meet the requirements of resistance according to Clause 15.5.5.4.

Contact paste shall not be used at the test.

15.7 Delivery

15.7.1 General
The client shall, according to these guidelines, approve the connector before delivery. On request form the client the manufacturer shall certify that inspection in accordance with Clause 15.7 have been carried out with approved results. For approval the manufacturer shall show that the connector conforms with these guidelines.

All documentation shall be written in Swedish or English.

15.7.2 Documentation
General requirements for documentation see SvK TR 08E.

15.7.2.1 Assembly drawing
The assembly drawing shall have a minimum of two views at an appropriate scale in accordance with SS-ISO 5455. On the drawing shall be given:

- Type and/or catalogue number
- Principal dimensions
The dimensions after installation
All marking.
Weight.
List of materials.
Required compression tools

15.7.2.2  List of material
Description of material in included parts.

15.7.2.3  Manufacturing process
Description of the manufacturing process.

15.7.2.4  Quality system
Quality system in accordance with SS-EN ISO 9001.

15.7.2.5  Installation instruction
Installation instructions in Swedish or English with the required figures.

15.7.2.6  Type test report
Type test report in accordance with Clause 15.6.

15.7.3  Transport and storing
The bolted connectors shall be packed up in that way that they will not be damaged or fouled at transport, construction and storing.

15.8  Installation

15.8.1  General
The installation shall be in accordance with the installation instruction.
When bolted connector is installed on the conductor in the vicinity of a dead end clamp the distance between the dead end clamp and the bolted connector shall be at least 500 mm.

When parallel grove clamps is installed on the conductor they shall always be installed two in series with a distance of one connector length in between.

15.8.2  Measurement of resistance
After installation the resistance shall be measured. The measurement shall be made over the entire connector from conductor to conductor R1 in the vicinity of the connector see Figure 10 and for the T-clamps also measurement of R2 from the conductor in the vicinity of the connector to above the lashing notch for branch conductor. Description of relevant procedure for the measurement can be found in EBR 303K.

The measured resistances, span number and in which conductor the connector is situated shall be kept in a record according to Figure 8 and in a data file.
Connector with resistance 10% greater than the resistance given in the type test report shall be dismantled and the contact surfaces shall be greased with contact paste and brushed with a steel brush and then reinstalled.
### 15.9 Tables

#### 15.9.1 Table 1  Bolted connectors with two current carrying parts for connection of parallel conductors

<table>
<thead>
<tr>
<th>Conductor designation</th>
<th>Current carrying surface</th>
<th>Contact force</th>
<th>Conductor designation</th>
<th>Current carrying surface</th>
<th>Contact force</th>
<th>Conductor groove length</th>
<th>Bolt</th>
<th>Bolt dimension</th>
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<td>A ( \text{mm}^2 )</td>
<td>F ( \text{kN} )</td>
<td>area ( \text{mm}^2 )</td>
<td>A ( \text{mm}^2 )</td>
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<td>70</td>
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### 15.9.2 Table 2 Bolted connectors with keepers for connection of conductors (T-clamp)

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<th>Conductor design</th>
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<th>Conductor groove length</th>
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<td>5900</td>
<td>4300</td>
<td>150</td>
<td>M10</td>
</tr>
</tbody>
</table>

### 15.9.3 Table 3 Tensile strength, hardness and resistivity of aluminium for bolted connectors

<table>
<thead>
<tr>
<th>Tensile strength</th>
<th>Hardness</th>
<th>Resistivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rp 0.2</td>
<td>Rm</td>
<td>A5</td>
</tr>
<tr>
<td>min. MPa</td>
<td>min. MPa</td>
<td>%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Separate cast test rod</th>
<th>Cast</th>
<th>Forged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rp 0.2</td>
<td>190</td>
<td>180</td>
<td>240</td>
</tr>
<tr>
<td>Rm</td>
<td></td>
<td>200</td>
<td>290</td>
</tr>
<tr>
<td>A5</td>
<td></td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>max. HB</td>
<td></td>
<td>75</td>
<td>85</td>
</tr>
<tr>
<td>max. n m</td>
<td></td>
<td>50</td>
<td>40</td>
</tr>
</tbody>
</table>

1) Values for machined test pieces manufactured from connector parts.

2) Values for current-carrying parts
### 15.9.4 Table 4  Steel conductor (Fe 140)

<table>
<thead>
<tr>
<th>Designation area</th>
<th>No’s of strands</th>
<th>Diameter Strand mm</th>
<th>Cond. mm</th>
<th>Calculated Mass kg/km</th>
<th>Calculated DC resistance1) Ω/km</th>
<th>DC resistance2) kΩ</th>
<th>Short circuit current2) kA</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>7</td>
<td>3.08</td>
<td>9.24</td>
<td>412</td>
<td>71,4</td>
<td>3,705</td>
<td>3,0</td>
</tr>
<tr>
<td>68</td>
<td>7</td>
<td>3.52</td>
<td>10.6</td>
<td>538</td>
<td>93,1</td>
<td>2,837</td>
<td>3,9</td>
</tr>
<tr>
<td>89</td>
<td>7</td>
<td>4.02</td>
<td>12.1</td>
<td>702</td>
<td>122</td>
<td>2,175</td>
<td>5,1</td>
</tr>
<tr>
<td>105</td>
<td>7</td>
<td>4.36</td>
<td>13.1</td>
<td>826</td>
<td>143</td>
<td>1,849</td>
<td>6,0</td>
</tr>
<tr>
<td>142</td>
<td>19</td>
<td>3.08</td>
<td>15.4</td>
<td>1127</td>
<td>194</td>
<td>1,375</td>
<td>8,2</td>
</tr>
<tr>
<td>185</td>
<td>19</td>
<td>3.52</td>
<td>17.6</td>
<td>1472</td>
<td>253</td>
<td>1,053</td>
<td>10,7</td>
</tr>
<tr>
<td>241</td>
<td>19</td>
<td>4.02</td>
<td>20.1</td>
<td>1920</td>
<td>331</td>
<td>0,8074</td>
<td>13,9</td>
</tr>
<tr>
<td>284</td>
<td>19</td>
<td>4.36</td>
<td>21.8</td>
<td>2258</td>
<td>390</td>
<td>0,6864</td>
<td>16,4</td>
</tr>
</tbody>
</table>

1) The DC resistance is calculated from the mean value of 192,0 nΩm (9,0% IACS) for the individual strand.
2) The short circuit current is the calculated effective value with a duration of one second at an initial conductor temperature of +30 °C and a final temperature of +300 °C.

### 15.9.5 Table 5  All aluminium conductor (AAC), (AL1)

<table>
<thead>
<tr>
<th>Designation accord. EN</th>
<th>Designation area</th>
<th>No’s of strands</th>
<th>Diameter Strand mm</th>
<th>Cond. mm</th>
<th>Calculated Mass kg/km</th>
<th>Calculated DC resistance1) Ω/km</th>
<th>DC resistance2) kΩ</th>
<th>Continuous current capacity3) A</th>
<th>Short circuit current3) kA</th>
</tr>
</thead>
<tbody>
<tr>
<td>454-AL1</td>
<td>454</td>
<td>61</td>
<td>3.08</td>
<td>27.7</td>
<td>1256</td>
<td>74,99</td>
<td>0,06366</td>
<td>406</td>
<td>43,5</td>
</tr>
<tr>
<td>594-AL1</td>
<td>593</td>
<td>61</td>
<td>3.52</td>
<td>31.7</td>
<td>1641</td>
<td>97,95</td>
<td>0,04874</td>
<td>433</td>
<td>56,9</td>
</tr>
<tr>
<td>774-AL1</td>
<td>774</td>
<td>61</td>
<td>4.02</td>
<td>36.2</td>
<td>2140</td>
<td>123,9</td>
<td>0,03737</td>
<td>483</td>
<td>74,2</td>
</tr>
<tr>
<td>911-AL1</td>
<td>910</td>
<td>61</td>
<td>4.36</td>
<td>39.2</td>
<td>2517</td>
<td>145,7</td>
<td>0,03177</td>
<td>519</td>
<td>87,3</td>
</tr>
</tbody>
</table>

1) The DC resistance is calculated from the mean value 28.035 nΩm (61.5 % IACS) of the individual strand.
2) The continuous current capacity is calculated for a conductor temperature of +50 °C at an ambient temperature of +30°C, frequency 50 Hz, resistivity temperature coefficient 0,00403, emission factor 0,7, absorption coefficient 0,9, wind velocity 0,6 m/s and at a latitude of 60° (N).
3) The short circuit current is the calculated effective value with duration of one second at an initial conductor temperature of +50°C and a final temperature of +200°C.
<table>
<thead>
<tr>
<th>Designation according to EN</th>
<th>Designation</th>
<th>No's of strands</th>
<th>Diameter</th>
<th>Calculated</th>
<th>DC resistance</th>
<th>Con tinuous current capacity</th>
<th>Short circuit current</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>area</td>
<td>Al</td>
<td>Fe</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>kg/km</td>
</tr>
<tr>
<td>Phase conductor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>402-AL1/52-ST1A</td>
<td>454</td>
<td>54</td>
<td>7</td>
<td>3,08</td>
<td>3,08</td>
<td>9,24</td>
<td>27,7</td>
</tr>
<tr>
<td>525-AL1/68-ST1A</td>
<td>593</td>
<td>54</td>
<td>7</td>
<td>3,52</td>
<td>3,52</td>
<td>10,6</td>
<td>31,7</td>
</tr>
<tr>
<td>685-AL1/89-ST1A</td>
<td>774</td>
<td>54</td>
<td>7</td>
<td>4,02</td>
<td>4,02</td>
<td>12,1</td>
<td>36,2</td>
</tr>
<tr>
<td>806-AL1/102-ST1A</td>
<td>910</td>
<td>54</td>
<td>19</td>
<td>4,36</td>
<td>2,62</td>
<td>13,1</td>
<td>39,3</td>
</tr>
<tr>
<td>Shield conductor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89-AL1/52-ST1A</td>
<td>142</td>
<td>12</td>
<td>7</td>
<td>3,08</td>
<td>3,08</td>
<td>9,24</td>
<td>15,4</td>
</tr>
<tr>
<td>152-AL1/89-ST1A</td>
<td>241</td>
<td>12</td>
<td>7</td>
<td>4,02</td>
<td>4,02</td>
<td>12,1</td>
<td>20,1</td>
</tr>
<tr>
<td>251-AL1/68-ST1A</td>
<td>319</td>
<td>32</td>
<td>7</td>
<td>3,16</td>
<td>3,52</td>
<td>10,6</td>
<td>23,2</td>
</tr>
</tbody>
</table>

Table 6. Aluminium conductor steel

^3)
1) The DC resistance is calculated from the mean value 28.264 nΩm (61 % IACS) of the individual strand.
2) The continuous current capacity is calculated for a conductor temperature of +50 °C at an ambient temperature of +30°C, frequency 50 Hz, resistivity temperature coefficient 0.0043, emission factor 0.7, absorption coefficient 0.9, wind velocity 0.6 m/s and at a latitude of 60° (N).
3) The short circuit current is the calculated effective value with duration of one second at an initial conductor temperature of +50°C and a final temperature of +200°C.
4) The short circuit current is the calculated effective value with duration of one second at an initial conductor temperature of +30°C and a final temperature of +200°C.

15.9.7 Table 7a AlMgSi-conductor

<table>
<thead>
<tr>
<th>Designation area</th>
<th>No’s of strands</th>
<th>Diameter Strand mm</th>
<th>Cond. Dia. mm</th>
<th>Calculated Mass kg/km</th>
<th>Rated-strength kN</th>
<th>DC resistance Ω/km</th>
<th>Continuous current capacity A</th>
<th>Short-circuit current kA</th>
</tr>
</thead>
<tbody>
<tr>
<td>454</td>
<td>61</td>
<td>3,08</td>
<td>27,7</td>
<td>1256</td>
<td>125,0</td>
<td>0,06755</td>
<td>393</td>
<td>43,2</td>
</tr>
<tr>
<td>593</td>
<td>61</td>
<td>3,52</td>
<td>31,7</td>
<td>1640</td>
<td>157,3</td>
<td>0,05172</td>
<td>419</td>
<td>56,4</td>
</tr>
<tr>
<td>774</td>
<td>61</td>
<td>4,02</td>
<td>36,2</td>
<td>2139</td>
<td>197,4</td>
<td>0,03965</td>
<td>471</td>
<td>73,6</td>
</tr>
<tr>
<td>910</td>
<td>61</td>
<td>4,36</td>
<td>39,2</td>
<td>2516</td>
<td>232,2</td>
<td>0,03371</td>
<td>503</td>
<td>86,6</td>
</tr>
</tbody>
</table>

1) The DC resistance is calculated from the mean value 30,000 nΩm (57.5% IACS) of the individual strand.
2) The continuous current capacity is calculated for a conductor temperature of +50 °C at an ambient temperature of +30°C, frequency 50 Hz, resistivity temperature coefficient 0.0038, emission factor 0.7, absorption coefficient 0.9, wind velocity 0.6 m/s and at a latitude of 60° (N).
3) The short circuit current is the calculated effective value with duration of one second at an initial conductor temperature of +50°C and a final temperature of +200°C.
### 15.9.8 Table 7b AlMgSi-conductor (AL7)

<table>
<thead>
<tr>
<th>Designation</th>
<th>Designation area</th>
<th>No's of strand</th>
<th>Diameter</th>
<th>Calculated</th>
<th>DC resistance</th>
<th>Continuous current capacity</th>
<th>Short-circuit current</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strand</td>
<td>Cond.</td>
<td>Mass</td>
<td>Rated strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mm</td>
<td>mm</td>
<td>kg/km</td>
<td>kN</td>
<td>Ω/km</td>
</tr>
<tr>
<td>454-AL7</td>
<td>454</td>
<td>61</td>
<td>3,08</td>
<td>27,7</td>
<td>1256</td>
<td>125,0</td>
<td>0,06755</td>
</tr>
<tr>
<td>594-AL7</td>
<td>593</td>
<td>61</td>
<td>3,52</td>
<td>31,7</td>
<td>1641</td>
<td>157,3</td>
<td>0,05172</td>
</tr>
<tr>
<td>774-AL7</td>
<td>774</td>
<td>61</td>
<td>4,02</td>
<td>36,2</td>
<td>2140</td>
<td>197,4</td>
<td>0,03965</td>
</tr>
<tr>
<td>911-AL7</td>
<td>910</td>
<td>61</td>
<td>4,36</td>
<td>39,2</td>
<td>2517</td>
<td>232,2</td>
<td>0,03371</td>
</tr>
</tbody>
</table>

1) The DC resistance is calculated from the mean value 30,000 nΩm (57,5% IACS) of the individual strand.
2) The continuous current capacity is calculated for a conductor temperature of +50 °C at an ambient temperature of +30°C, frequency 50 Hz, resistivity temperature coefficient 0,0038, emission factor 0,7, absorption coefficient 0,9, wind velocity 0,6 m/s and at a latitude of 60° (N).
3) The short circuit current is the calculated effective value with duration of one second at an initial conductor temperature of +50°C and a final temperature of +200°C.

### 15.9.9 Table 8 Al59-linor

<table>
<thead>
<tr>
<th>Designation</th>
<th>No's of strands</th>
<th>Diameter</th>
<th>Calculated</th>
<th>DC resistance</th>
<th>Continuous current capacity</th>
<th>Short-circuit current</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Strand</td>
<td>Cond.</td>
<td>Rated strength</td>
<td>Mass</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mm</td>
<td>mm</td>
<td>kN</td>
<td>kg/km</td>
<td></td>
</tr>
<tr>
<td>454</td>
<td>61</td>
<td>3,08</td>
<td>27,7</td>
<td>1250</td>
<td>113,6</td>
<td>0,06532</td>
</tr>
<tr>
<td>593</td>
<td>61</td>
<td>3,52</td>
<td>31,7</td>
<td>1640</td>
<td>142,5</td>
<td>0,05001</td>
</tr>
<tr>
<td>774</td>
<td>61</td>
<td>4,02</td>
<td>36,2</td>
<td>2140</td>
<td>178,1</td>
<td>0,03834</td>
</tr>
<tr>
<td>910</td>
<td>61</td>
<td>4,36</td>
<td>39,2</td>
<td>2510</td>
<td>209,5</td>
<td>0,03260</td>
</tr>
</tbody>
</table>

1) The DC resistance is calculated from the mean value 29,050 nΩm (59,4% IACS) of the individual strand.
2) The continuous current capacity is calculated for a conductor temperature of +50 °C at an ambient temperature of +30°C, frequency 50 Hz, resistivity temperature coefficient 0,0039, emission factor 0,7, absorption coefficient 0,9, wind velocity 0,6 m/s and at a latitude of 60° (N).
3) The short circuit current is the calculated effective value with duration of one second at an initial conductor temperature of +50°C and a final temperature of +200°C.
15.10 Figures

Figure 1 Bolted connectors with two current carrying parts for connection of parallel conductors

Figure 2 Bolted connectors with keepers for connection of conductors (T-clamp)
Figure 3  Current-carrying contact surface in bolted connectors with two current-carrying parts

Figure 4  Current-carrying contact surface in bolted connectors with keepers
Figure 5  Contact surface of keepers in bolted connectors

Figure 6  Contact force in bolted connectors with two current-carrying parts

Figure 7  Contact force in bolted connectors with keepers
Figure 8  Measurement of resistance, type test

Figure 9  Measurement of resistance, type test
Figure 10  Measurement of resistance, installation records

Conductor numbering

Phase

Triplex

Duplex

Towards greater structure number

Bolted connector type

Parallel groove clamp

T-clamp

Line: .......................................................... Line designation: .....................................
  ..........................................................
Conductor A: .............................................. Conductor B: ..................................
  ..........................................................

<table>
<thead>
<tr>
<th>Span No</th>
<th>Conductor No</th>
<th>Bolted Connector Type</th>
<th>Measured resistance $R_1$ $\mu\Omega$</th>
<th>$R_2$ $\mu\Omega$</th>
<th>Installation performed Datum</th>
<th>Signature</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</table>

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