XLPE AC Land Cable Systems
User´s Guide

U.S. Standard Rev 3

Power and productivity
for a better world™

ABB

CONTENT

XLPE AC Land Cable Systems

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INTRODUCTION

Interfaces you can trust
ABB manufactures land and submarine power cables up to the highest voltages available on the market.

Furthermore, we produce the associated joints, terminations and other accessories for all types of cables.

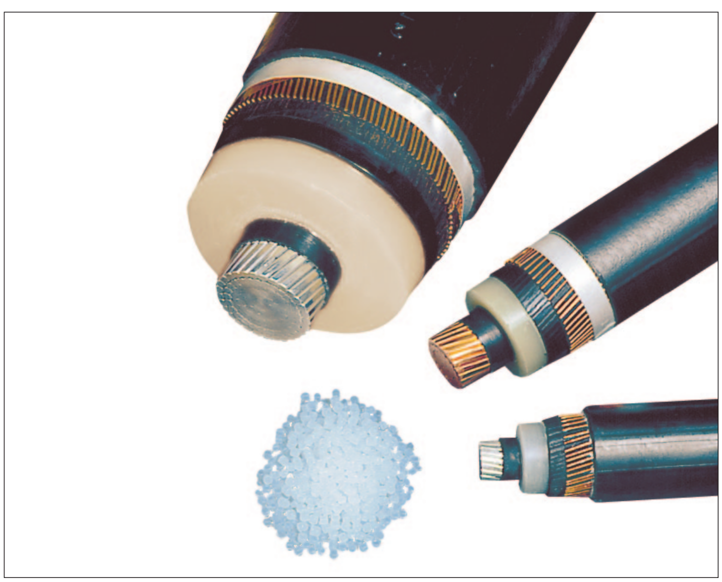
Experience you can rely on
We have extensive experience of cable projects all over the world, encompassing every aspect from planning to commissioning, including engineering, route surveys, cable-laying, installation and final testing. Very few manufacturers can point to such a long tradition in the high voltage field as ABB. We delivered our first electrical cable in 1883 and introduced triple-extruded XLPE cables around 1970. In the early 1970s we started to supply cables for over 100 kV and our first 245 kV XLPE cable was put into service in 1978. ABB has since then supplied more than 5,500 miles of XLPE cables above 100 kV. Experience you can rely on.

XLPE advantages
Today the vast majority of new 230 kV and 345 kV underground circuits in North America have shifted from high pressure fluid-filled (HPFF) to XLPE cables. Improvements in material characteristics and manufacturing processes throughout the years have allowed XLPE cables to provide constantly improving reliability despite the voltage stresses per mil of insulation having continuously increased. Today these cables operate at or above the level of HPFF cable reliability. Additionally, these cables are environmentally friendly and generally considered maintenance free. XLPE cable also has economical and technical advantages over HPFF cable, such as significantly lower power losses. Besides reducing dielectric and charging current losses, the reduced capacitance allows for less voltage variations during switching, less equipment required for reactive power compensation, and higher load carrying capability. All of these advantages add up to making XLPE the preferred insulation technology throughout the world.

Research and development
ABB has been a pioneer in the high voltage field and we have many world's first and world records among our references. But there are no shortcuts to success. Maintaining our position calls for innovative research and development, backed by the wealth of know-how we have accumulated over the years. One of the driving forces for our R&D is to meet the new and constantly increasing requirements from the power industry and deregulated market. Today we aim to develop the solutions our customers will need tomorrow.

State-of-the-art manufacturing lines
Expertise and state-of-the-art technology go hand in hand for us. We have been manufacturing cables for over 125 years and have since been one of the leading producers in the industry. Our manufacturing plants are among the most modern in the world and our advanced quality system leaves nothing to chance. Every cubic inch of the cable has to be perfect. We design and produce cables in accordance with international and national standards and/or according to our customers' specifications.

This guide presents XLPE cables and systems for land applications mainly. For subsea applications please refer to "XLPE Submarine Cable Systems".



DESIGN, INSTALLATION AND TESTING

XLPE cables

XLPE cables consist of the following components:
- Conductor
  - Copper (Cu) or Aluminum (Al) stranded compacted conductor or
  - Cu segmental conductor or
  - Cu or Al conductor with key-stone shaped profiles
  - Longitudinal water sealing of conductor
- Triple extruded and dry cured XLPE insulation system
- Metallic shield/sheath
  - Copper wire shield
  - Copper tape shield
  - Radial moisture barrier
    - Metallic laminate solidly bonded to outer polyethylene jacket or
    - Lead sheath
  - Longitudinal water sealing of metallic shield
- Non-metallic outer jacket
  - PE
  - PVC
  - Halogen free flame retardant
  - Co-extruded conductive layer over the jacket for jacket integrity testing

Cable accessories

ABB's line-up of cable accessories for ABB XLPE cable systems includes:

- Straight joints and joints with integrated shield separation for cross bonding
- Outdoor terminations with porcelain or composite insulators
- Shielded separable connectors for switchgears and transformers
- Cable terminations for transformers and Gas Insulated Switchgears (GIS)
- Link boxes for earthing and cross-bonding
- Distributed Temperature Sensing (DTS) Systems with integrated optical fiber in metallic tube (FIMT)

More information about our accessories is available on www.abb.com

DESIGN, INSTALLATION AND TESTING

Installation of XLPE cable systems

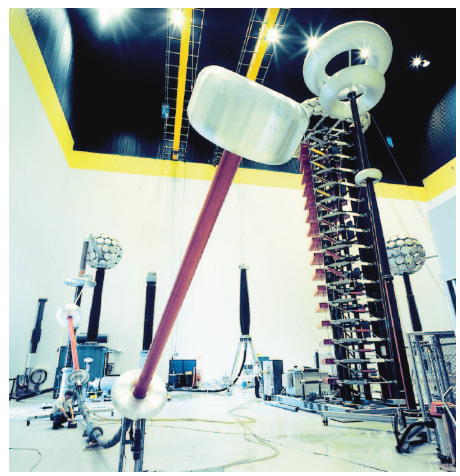
Installation of cable systems includes trenching, cable pulling, clamping of cable, cable splicing and mounting of accessories. High quality installation work performed by ABB certified field personnel is essential for achieving the low failure rates and reliability performance that is expected from modern underground transmission and distribution circuits.

ABB has long and extensive experience from different types of cable installations including not only direct burial, duct, shaft, trough, tunnel and submarine installations, but also trenchless technologies like directional drilling, pipe jacking and others.

Testing of XLPE cable systems

Standard routine, sample, type and after laying tests are normally performed according to either AEIC, ICEA, or IEC standards.

Routine tests of XLPE cables and accessories
- PD measurement test
- High-voltage test of main insulation
- Electrical test of jacket
- Visual inspection



Sample tests
Sample tests are carried out with a frequency according to applicable standards.

- Conductor examination
- Electrical resistance of conductor
- Check of dimensions
- Capacitance test
- Hot set test
- Electrical tests

After laying tests
- DC voltage test of jacket
- AC voltage test of main insulation

XLPE CABLE AND CABLE SYSTEM STANDARDS

ABB´s XLPE cable systems are designed to meet requirements of international and/or national standards. Some of these are listed below.

IEC

XLPE cable systems specified according to IEC (International Electrotechnical Commission) are among many other standards accepted. IEC standards are considered to express an international consensus of opinion.

Some frequently used standards are:

IEC 60228
Conductors of insulated cables.

IEC 60287
Electric cables - Calculation of the current rating.

IEC 60332
Tests on electric cables under fire conditions.

IEC 60502
Power cables with extruded insulation and their accessories for rated voltage from 1 kV (Um=1.2 kV) up to 30 kV (Um=36 kV).

IEC 60840
Power cables with extruded insulation and their accessories for rated voltage above 30 kV (Um=36 kV) up to 150 kV (Um=170 kV). Test methods and requirements.

IEC 60853
Calculation of the cyclic and emergency current rating of cables.

IEC 61443
Short-circuit temperature limits of electric cables with rated voltages above 30 kV (Um=36 kV).

IEC 62067
Power cables with extruded insulation and their accessories for rated voltage above 150 kV (Um=170 kV) up to 500 kV (Um=550 kV). Test methods and requirements.

ICEA & AEIC

Cables installed in North America are often specified according to ICEA (Insulated Cable Engineers Association, Inc.) and AEIC (Association of Edison Illuminating Companies, Inc.).

Some frequently used standards are:

ICEA P-45-482
Short circuit performance of metallic shields and sheaths on insulated cables.

ICEA S-93-639
5-46 kV shielded power cable for use in the transmission and distribution of electric energy.

ICEA S-94-649
Standard for concentric neutral cables rated 5 through 46 kV.

ICEA S-97-682
Utility shielded power cables 5-46 kV.

ICEA S-108-720
Standard for extruded insulation power cables rated above 46 through 345 kV.

AEIC CS8
Specification for extruded dielectric shielded power cables rated 5 through 46 kV.

AEIC CS9
Specification for extruded insulation power cables and their accessories rated above 46 kV through 345 kVac.

ISO Standards

ABB has well-developed systems for quality and environmental management which put the needs and wishes of the customer first. Our systems comply with the requirements of ISO 9001 and ISO 14001 and are certified by Bureau Veritas Quality International.

ISO 14001 and ISO 9001
Certificate of Approval

XLPE AC LAND CABLE SYSTEM CONFIGURATIONS

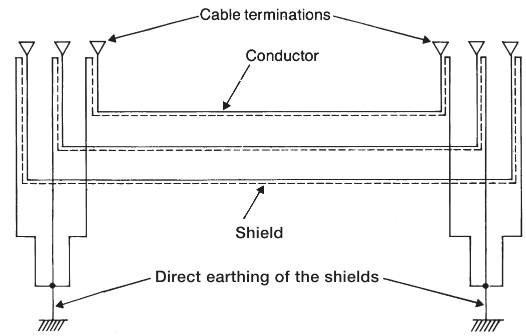
Trefoil and flat formation

The choice depends on factors such as metallic shield bonding method, conductor area and available space for installation.

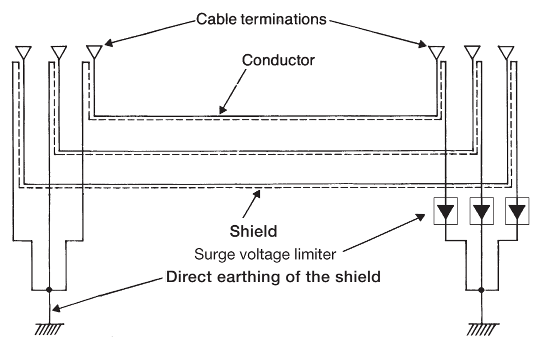
Bonding of the metallic shields

The electric power losses in a cable circuit are dependent on the currents flowing in the metallic shields of the cables. Therefore, by reducing or eliminating the metallic shield currents through different methods of bonding, it is possible to increase the load current carrying capacity (ampacity) of the cable circuit. Common bonding methods are described below:

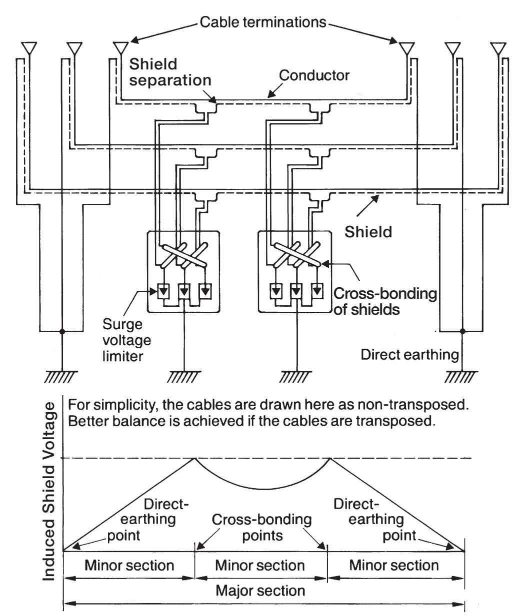
Both-ends bonding
A system is both ends bonded if the arrangements are such that the cable shields provide a path for circulating currents under normal conditions. This will cause losses in the metallic shield, which reduce the cable current carrying capacity. These losses are smaller for cables in trefoil formation than in flat formation with separation.



Single-point bonding
A system is single point bonded if the arrangements are such that the cable shields provide no path for the flow of circulating currents or external fault currents. In such case, a voltage will be induced between metallic shields of adjacent phases of the cable circuit and between shield and earth, but no current will flow. This induced voltage is proportional to the cable length and current. Single-point bonding can only be used for limited route lengths, but in general the accepted shield voltage potential limits the length.



Cross-bonding
A system is cross-bonded if the arrangements are such that the circuit provides electrically continuous metallic shield runs from earthed termination to earthed termination but with the metallic shields sectionalized and cross-connected in order to eliminate circulating currents. In such case, a voltage will be induced between shield and earth, but no significant current will flow. The maximum induced voltage will appear at the link boxes for cross-bonding. This method permits a cable current-carrying capacity as high as with single-point bonding but with longer route lengths. It requires shield separation and additional link boxes.



CURRENT RATING FOR XLPE AC LAND CABLE SYSTEMS

The XLPE cable should at least have a conductor cross section area adequate to meet the system requirements for power transmission capacity. The cost of energy losses can be reduced by using a larger conductor.

Load losses in XLPE cables are primarily due to the ohmic losses in the conductor and the metallic shield. XLPE cables can be loaded continuously to a conductor temperature of 90°C.

The dielectric losses in the XLPE insulation system are also present at no load current and depend primarily on the magnitude of the operating voltage.

Dielectric losses in XLPE cables are lower than in EPR and fluid-filled cables.

The continuous current ratings are calculated according to the IEC 60287 series of standards and with the following conditions: according to figures 1, 2 and 3.

Rating factors for single-core cables are given in Tables 5-10.

fig. 1

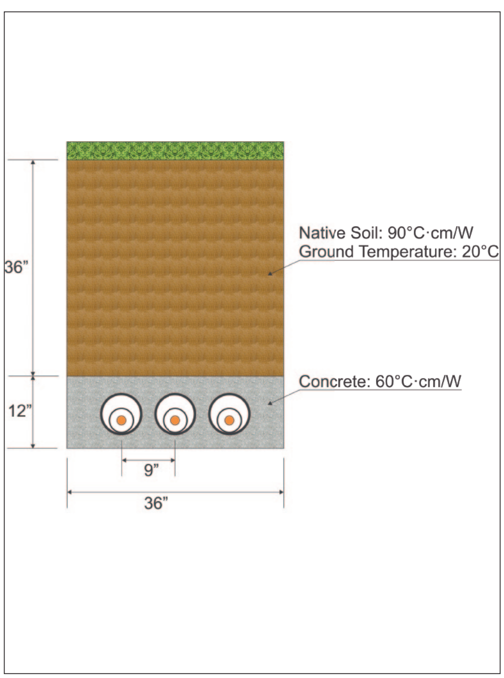


fig. 2

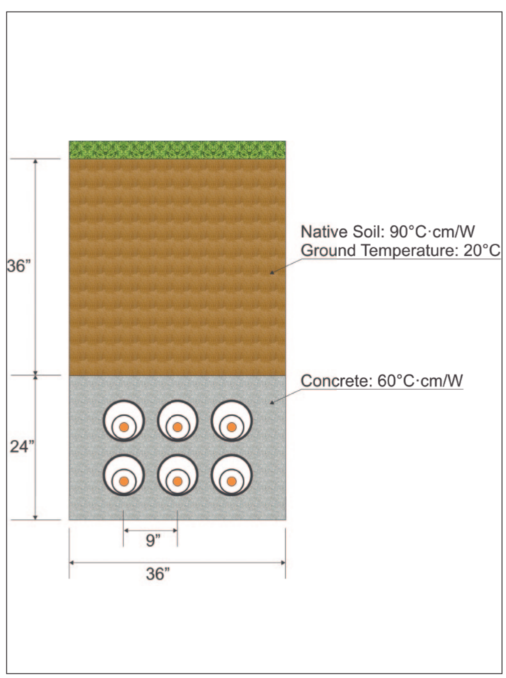
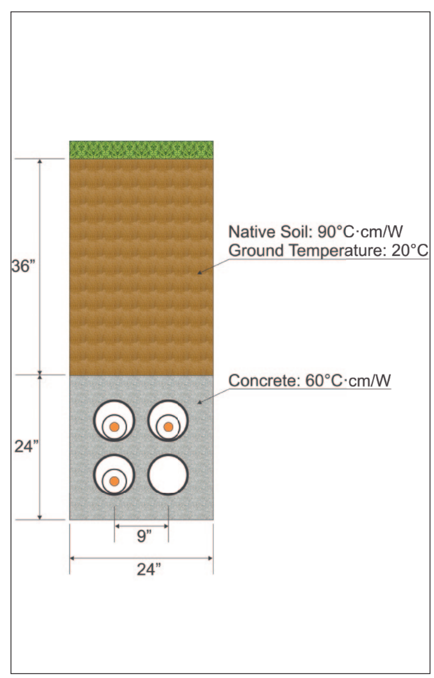


fig. 3



CURRENT RATING FOR XLPE AC LAND CABLE SYSTEMS

Current rating for single-core cables, amperes

Table 1

Rated voltage 69-138 kV, aluminum conductor - 180 kcmil metallic shield												
	Load factor 100%						Load factor 75%					
Conductor cross section	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded
kcmil	A	A	A	A	A	A	A	A	A	A	A	A
500	465	385	465	390	395	320	510	425	510	430	450	370
750	575	455	580	460	485	380	630	510	635	515	555	440
1000	670	505	675	510	565	415	745	570	745	570	650	485
1250	755	545	760	550	630	445	835	615	840	620	730	520
1500	830	575	835	580	695	470	925	655	930	660	800	550
1750	895	605	905	610	745	490	1000	690	1005	690	865	580
2000	950	625	960	630	790	505	1060	710	1070	715	915	595
2500	1055	660	1065	665	875	530	1185	760	1190	765	1015	630
3000	1140	690	1150	695	940	550	1280	795	1290	800	1095	655
3500	1205	705	1215	715	990	565	1355	815	1365	825	1160	675
4000	1265	730	1275	735	1040	580	1425	845	1435	855	1215	695
4934	1340	765	1350	770	1095	605	1515	890	1525	895	1285	725

Table 2

Rated voltage 69-138 kV, copper conductor - 180 kcmil metallic shield												
	Load factor 100%						Load factor 75%					
Conductor cross section	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded
kcmil	A	A	A	A	A	A	A	A	A	A	A	A
500	590	450	595	455	505	375	650	500	650	505	575	435
750	730	525	735	525	615	430	805	590	805	590	705	505
1000	845	570	855	575	710	465	935	645	940	645	820	545
1250	945	605	950	610	790	490	1045	685	1055	690	910	580
1500	1030	630	1035	635	860	510	1145	720	1150	725	990	605
1750	1100	655	1105	660	915	530	1225	750	1230	755	1060	625
2000	1160	670	1165	680	960	540	1290	770	1300	775	1115	640
2500	1385	730	1395	735	1145	580	1555	845	1565	850	1335	695
3000	1505	755	1520	765	1240	600	1695	880	1705	885	1450	720
3500	1575	780	1590	785	1295	615	1775	905	1785	915	1515	740
4000	1615	790	1625	800	1325	625	1820	920	1835	930	1550	750
4934	1630	820	1640	830	1330	645	1845	960	1855	970	1560	780

CURRENT RATING FOR XLPE AC LAND CABLE SYSTEMS

Table 3

Rated voltage 230-345 kV, aluminum conductor - 500 kcmil metallic shield												
	Load factor 100%						Load factor 75%					
Conductor cross section	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded
kcmil	A	A	A	A	A	A	A	A	A	A	A	A
1000	650	530	655	535	550	435	720	595	725	600	630	510
1250	725	570	735	575	610	470	805	645	810	650	705	550
1500	800	610	805	615	670	495	885	690	890	695	770	585
1750	865	635	870	640	720	515	960	725	965	730	835	610
2000	915	655	925	665	760	530	1020	750	1025	755	885	630
2500	1015	695	1025	700	840	560	1135	795	1145	805	980	665
3000	1095	725	1105	730	900	580	1225	835	1235	840	1055	690
3500	1155	745	1165	750	950	595	1295	860	1305	865	1110	710
4000	1210	765	1220	775	990	610	1365	885	1375	890	1165	730
4934	1285	790	1295	800	1050	625	1450	920	1460	925	1235	755

Table 4

Rated voltage 230-345 kV copper conductor - 500 kcmil metallic shield												
	Load factor 100%						Load factor 75%					
Conductor cross section	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	Single circuit single point bonding/ cross bonding	Single circuit both ends bonded	2 circuits single point bonding/ cross bonding	2 circuits both ends bonded
kcmil	A	A	A	A	A	A	A	A	A	A	A	A
1000	820	610	825	615	695	500	905	685	910	690	795	585
1250	910	650	915	655	760	525	1005	735	1010	740	880	620
1500	990	680	995	685	825	550	1095	775	1100	780	955	650
1750	1055	700	1065	710	880	565	1175	800	1180	805	1020	670
2000	1110	720	1120	725	925	580	1240	825	1245	830	1070	690
2500	1325	780	1335	785	1095	620	1485	895	1495	905	1275	740
3000	1440	805	1450	815	1185	640	1615	935	1625	940	1385	770
3500	1500	825	1510	835	1230	650	1690	955	1700	965	1440	785
4000	1535	835	1545	845	1255	660	1730	970	1740	980	1475	795
4934	1550	850	1565	860	1260	670	1755	995	1770	1000	1490	810

CURRENT RATING FOR XLPE AC LAND CABLE SYSTEMS

Rating factors

Rating factors for metallic shield

The rating factors in Tables 5 & 6 are applicable to single-core cables in flat and trefoil formation with the shields bonded at both ends.

These rating factors are not necessary for single-point bonded or cross-bonded systems.

Table 5 **69-138 kV 180 kcmil metallic shield**

Rating factor for tables 1 and 2						
Conductor kcmil		Copper shield kcmil				
Al	**Cu**	**45**	**90**	**180**	**360**	**500**
500		1.07	1.03	1.00	1.02	1.04
750		1.08	1.03	1.00	1.01	1.04
1000	500	1.09	1.04	1.00	1.02	1.04
1250	750	1.10	1.05	1.00	1.01	1.04
1500	1000	1.11	1.05	1.00	1.01	1.04
1750	1250	1.12	1.06	1.00	1.01	1.04
2000	1500	1.13	1.06	1.00	1.01	1.04
2500	1750	1.13	1.06	1.00	1.00	1.04
3000	2000	1.14	1.06	1.00	1.00	1.03
3500	2500	1.15	1.07	1.00	1.00	1.03
4000	3000	1.15	1.07	1.00	1.00	1.03
4934	3500	1.15	1.07	1.00	0.99	1.02
	4000	1.16	1.07	1.00	0.99	1.02
	4934	1.15	1.07	1.00	0.99	1.01

Table 6 **230-345 kV 500 kcmil metallic shield**

Rating factor for tables 3 and 4					
Conductor kcmil		Copper shield kcmil			
Al	**Cu**	**90**	**180**	**360**	**500**
1000		1.01	0.98	0.98	1.00
1250		1.02	0.99	0.98	1.00
1500	1000	1.02	0.98	0.98	1.00
1750	1250	1.03	0.98	0.98	1.00
2000	1500	1.03	0.99	0.98	1.00
2500	1750	1.04	0.99	0.98	1.00
3000	2000	1.04	0.99	0.98	1.00
3500	2500	1.05	0.99	0.98	1.00
4000	3000	1.05	0.99	0.98	1.00
4934	3500	1.06	1.00	0.98	1.00
	4000	1.06	0.99	0.98	1.00
	4934	1.06	1.00	0.98	1.00

1 kcmil copper shield is equivalent to:
1.66 kcmil aluminum shield
12.40 kcmil lead sheath

Rating factors for installation conditions

Table 7

Rating factor for laying depth	
Laying depth, ft	Rating factor
1	1.11
2	1.04
3	1.00
4	0.97
5	0.95
10	0.89

Table 8

Rating factor for ground temperature								
Ground temperature, °C	10	15	20	25	30	35	40	45
Rating factor	1.07	1.03	1.00	0.96	0.93	0.89	0.85	0.80

Table 9

Rating factor for ground thermal resistivity							
Thermal resistivity, °C·cm/W	60	90	120	150	200	250	300
Rating factor	1.09	1.00	0.93	0.87	0.79	0.73	0.68

Table 10

Rating factor for center-to-center spacing between conduits					
Spacing s, inches	7	9	11	13	15
Single/cross bonded	0.98	1.00	1.02	1.03	1.04
Both ends bonded	1.03	1.00	0.98	0.97	0.96

Example of the use of rating factors

One group of 138 kV XLPE cables with 2000 kcmil copper conductors and 90 kcmil copper shields are installed underground in flat formation. The cables are running at 100% load factor and are bonded at both ends. The duct bank is buried 4' and the conduits are spaced 13" center-to-center. The soil has a thermal resistivity of 120°C·cm/W and a temperature of 15°C. Table 2 gives a current rating of 670 A, unadjusted value.

		Table	Rating factor
Current rating	670 A	2	-
Shield area	90 kcmil	5	1.06
Laying depth	4'	7	0.97
Ground temperature	15ºC	8	1.04
Ground thermal resistivity	120°C·cm/W	9	0.93
Conduit Spacing	13"	10	0.97

Adjusted current rating per group;

670 x 1.06 x 0.97 x 1.04 x 0.93 x 0.97 = 646 A

Please note that use of rating factors gives good general indication for planning future circuits.
Once a circuit layout is defined, an accurate calculation should be performed to confirm the assumptions.

Overload capacity

An XLPE cable may be overloaded up to 105°C. Singular emergency events are not expected to have any significant impact on the service life of the cable. The number and duration of overloads should be kept low. Cyclic and emergency ratings can be calculated according to IEC publication 60853.

Short-circuit currents

During short circuit events the maximum allowable temperature in the conductor or metallic shield/sheath is determined by the adjoining insulation and jacket materials. This is specified in IEC 61443 "Short circuit temperature limits of electric cables with rated voltage above 30 kV (Um=36 kV)" and ICEA P-45-482 "Short circuit performance of metallic shields and sheaths on insulated cables". The dynamic forces between the conductors must also be taken into account for cable installations.

Maximum short circuit currents due to thermal restrictions
The thermal energy produced during a short-circuit is determined by the short-circuit magnitude and duration. For design purposes, an equivalent short-circuit current with a duration of 1 second is used according to the formula below. This formula is valid for a short-circuit duration of 0.2 to 5.0 seconds.

$$I_{sh} = \frac{I_1}{\sqrt{t_{sh}}} \quad [kA]$$

I_{sh}= short-circuit current [kA] during time t_{sh}

I_1 = short-circuit current rating during 1 second. See the 1 second value in Table 11 for the conductor and Table 12 for the metallic shield.

t_{sh}= short-circuit duration (sec)

For XLPE insulated conductors the maximum allowable short circuit temperature is 250°C.

Table 11

Max. short-circuit current on the conductor during 1 s, kA				
Conductor temperature before the short-circuit				
Cross section	Aluminum conductor		Copper conductor	
kcmil	65°C	90°C	65°C	90°C
500	26.1	23.9	39.6	36.2
750	39.3	35.9	59.6	54.4
1000	52.4	47.9	79.5	72.5
1250	65.5	59.8	99.2	90.6
1500	78.6	71.8	119	108
1750	91	83.8	139	126
2000	104	95.7	158	145
2500	131	119	198	181
3000	157	143	238	217
3500	183	167	278	253
4000	209	191	317	290
4934	258	236	392	357
per kcmil	0.0525	0.0479	0.0795	0.0725

Copper shields may reach a temperature of 250°C without damaging adjacent insulating material. With an initial temperature of 50°C, this corresponds to a current density of 83 A/kcmil during a 1 second fault (both higher and lower current densities may be allowed if other conditions apply).

Lead sheath temperatures of up to 210°C are permitted during short circuit events. With an initial temperature of 50°C, this corresponds to a current density of 14 A/kcmil during a 1 second fault.

Table 12

Max. short-circuit current on the metallic shield during 1 s, kA			
Metallic shield cross section, kcmil		Metallic shield temperature before the short-circuit	
Copper shield	Lead sheath	50°C	70°C
45	311	3.7	3.5
90	621	7.5	7.0
180	1242	14.9	14.0
360	2484	30	28
500	3450	42	39
750	5175	62	58
per kcmil Cu		0.083	0.0776
	per kcmil Pb	0.0142	0.0132

Dynamic forces during short circuit events

In addition to the thermal stresses, the dynamic forces in the cables and accessories during a short circuit event must also be considered.

The dynamic effect of parallel conductors carrying current is responsible for the dynamic force.

The dynamic force between two conductors, can be calculated as:

$$F = \frac{0.53}{S} \cdot I_{peak}^2 \; [lbf/ft]$$

Where; I_{peak} = 2.5 I_{sh} [kA]

I_{sh} = Short-circuit current [kA] RMS

S = Center to center spacing between conductors [inches]

F = Maximum force [lbf/ft]

CABLE REELS - TESTING - CABLE HANDLING

Selection of cable reel

Standard wooden and steel reel sizes are available. Both wooden and steel reels can be obtained for special purposes with other dimensions than stated below.

Table 13

Cable lengths in feet on standard wooden reels and steel reels																			
Dia. inches	Wooden reel										Steel reel								
	K16	K18	K20	K22	K24	K26	K28	K30	K321-20	K321-22	St 30	St 32	St 34	St 35	St 36	St 37	St 38	St 39	St 40
1.5	2093	2709	3687	4438	6095	8451													
1.6	2014	2263	3110	3799	5367	7545	10787												
1.7	1643	2171	2877	3513	4973	7106	10751	13513											
1.8	1574	1768	2365	3382	4314	6266	9238	12349	14658										
1.9	1181	1601	2171	2703	3540	5301	8070	10649	12316	10751									
2.0	1190	1341	1827	2326	3572	5131	7148	9583	12106	9343	9504								
2.1	1128	1266	1742	2221	3001	4402	6026	9028	10429	8917	9120	11555							
2.2	1059	1190	1656	2109	2857	4238	6085	8038	10223	8727	8730	11076	13569						
2.3	800	902	1276	1676	2368	3425	5095	6883	8477	7060	7106	9248	11538	12739	12431				
2.4	807	908	1200	1581	2237	3451	4908	6955	8277	6879	6948	9055	11305	12486	12171	11748			
2.5	751	843	1207	1591	2253	2851	4179	6066	7116	5744	5810	7805	9944	11069	10715	10255	10606		
2.6		784	1141	1213	1811	2732	4035	5039	6738	5423	5524	7434	8448	9494	10219	9767	10095	10426	10754
2.7		787	1062	1131	1692	2588	3372	5085	5685	5262	5377	6292	8238	9265	8874	8395	8684	8973	9258
2.8		606	823	1138	1702	2211	3398	4885	5511	4268	5229	6125	8024	9028	8641	8169	8448	8727	9002
2.9		554	764	1056	1581	2086	3234	4137	5337	4127	4245	5951	7808	7808	8405	7936	8205	8474	8743
3.0			770	1066	1325	1971	2660	3979	4422	3999	3986	4776	6466	7362	6965	6492	6715	6938	7162
3.1			708	980	1223	1984	2677	4012	4265	3854	4002	4799	6502	7411	7004	6522	6745	6968	7191
3.2			711	757	1230	1650	2529	3330	4288	3871	3871	4645	6299	6299	6781	6312	6525	6738	6955
3.3			715	761	1236	1541	2545	3353	4127	3021	3740	4488	5272	6092	5685	6095	6302	6509	6715
3.4			469	698	908	1437	2030	3202	3986	2910	2926	4350	5114	5918	5511	5042	5213	5387	5561
3.5				702	915	1446	2043	2769	3179	2785	2936	3635	5141	5141	5538	5062	5236	5410	5580
3.6				702	918	1453	2057	2611	3192	2795	2824	3497	4954	4954	5331	4872	5036	5203	5367
3.7				636	830	1167	1919	2627	3054	2670	2709	3359	4041	4763	4360	4678	4835	4996	5154
3.8						1082	1591	2483	2926	2552	2604	3231	3894	4593	4199	3753	3881	4012	4143
3.9						1085	1482	2103	2936	1984	2614	3244	3914	3914	4215	3766	3894	4025	4156
4.0						1092	1492	2116	2949	1988	2024	3261	3930	3930	4235	3779	3907	4038	4169
4.1						1000	1381	1988	2263	1896	1942	2516	3129	3779	3375	3625	3746	3871	3996
4.2						1003	1387	1998	2145	1794	1850	2398	2985	3605	3218	3454	3572	3690	3809
4.3									2155	1797					3231	3467	3585	3700	3818
4.4										1804					3244	3477	3595	3713	3832
4.5										1706					3097	2677	2769	2860	2952
4.6										1712					2936	2536	2621	2709	2798
4.7																2542	2627	2716	2805
4.8																2549	2637	2723	2811
4.9																2414	2496	2578	2660
5.0																2421	2503	2585	2667
5.1																	2509	2591	2673
5.2																	2365	2444	2519
5.3																		1889	1952
5.4																		1893	1955
5.5																			1830
5.6																			1837

CABLE REELS - TESTING - CABLE HANDLING

Sizes and weights of wooden reels and steel reels

Table 14

		Wooden reels - reel type									
		K16	K18	K20	K22	K24	K26	K28	K30	K321-20	K321-22
Shipping volume	ft³	101.0	126.4	180.8	217.2	259.9	372.9	490.2	605.6	831.7	831.7
Reel weight incl. battens	lbs	606	705	1069	1246	1378	2524	3219	4012	4409	4409
a Diameter incl. battens	inch	65.9	73.8	81.7	89.6	97.4	105.4	113.2	121.1	129.0	129.0
b Flange diameter	inch	63.0	70.9	78.7	86.6	94.5	102.4	110.2	118.1	126.0	126.0
c Drum diameter	inch	37.4	43.3	51.2	55.1	55.1	59.1	59.1	59.1	78.7	86.6
d Total width	inch	40.1	42.3	46.8	46.8	47.2	57.0	65.0	70.9	90.6	90.6
e Spindle hole diameter	inch	4.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Max. load	lbs	5512	6614	7716	9921	11023	22046	26455	28660	28660	28660

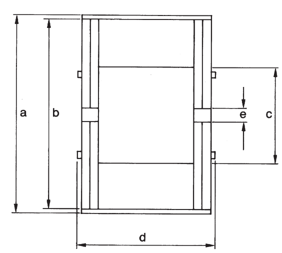
		Steel reels - reel type								
		St 30	St 32	St 34	St 35	St 36	St 37	St 38	St 39	St 40
Shipping volume	ft³	829.9	939.4	1020.6	1115.9	1179.5	1243.1	1306.6	1373.7	1444.4
Reel weight incl. battens	lbs	3748	4850	5732	5952	6173	6614	6834	7275	7716
a Diameter incl. battens	inch	123.2	131.1	139.0	142.9	146.9	150.8	154.7	158.7	162.6
b Flange diameter	inch	118.1	126.0	133.9	137.8	141.7	145.7	149.6	153.5	157.5
c Drum diameter*	inch	78.7	78.7	78.7	78.7	86.6	94.5	98.4	102.4	106.3
d Total width	inch	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5	94.5
e Spindle hole diameter	inch	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Max. load	lbs	52911	52911	52911	52911	52911	52911	52911	52911	52911

* May vary depending on cable design

Large and special reels

Steel reels with larger outer diameters are available, but transport restrictions have to be considered. Special lowloading trailers and permits from traffic authorities might be needed depending on local regulations and conditions.

Special wooden reels with larger drum diameters or larger widths are also available.



a Diameter incl. battens
b Flange diameter
c Drum diameter
d Total width
e Spindle hole diameter

Testing of XLPE cables

Table 15

Rated voltage and corresponding test voltages according to AEIC CS9 and ICEA S-108-720				
	Type test	Routine tests		
Nominal voltage	Impulse voltage	AC voltage test		Partial discharge test at
kV	kV	kV	Duration minutes	kV
69	350	100	30	60
115	550	160	30	100
138	650	200	30	120
230	1050	330	30	200
345	1300	400	60	300

Cable handling

Minimum bending radius

Table 16

Minimum bending radius for single core cables		
	Std cable design*	Special cable design**
At laying	15 D_e	18 D_e
When installed	10 D_e	12 D_e

D_e is the external diameter of the cable

* Cu-wire shield only
** Metallic laminated or lead sheathed cables or cables with integrated optical fibers

Maximum pulling forces

The following pulling forces should not be exceeded:

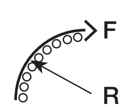
Aluminum conductors 4.5 lbs/kcmil
Copper conductors 8.0 lbs/kcmil

Maximum side wall pressure (SWP)

The following SWPs should not be exceeded:

Buried installation (rollers placed close) 345 lbs/ft*
Duct installation 515 lbs/ft*

$$SWP = \frac{F}{R} \text{[lbs/ft]}$$



* Depending on cable design and installation conditions higher values may be accepted.

Conductors

Table 17

Cross section		Diameter approx.	Maximum d.c. resistance at 25°C, ohm/1000 ft	
mm²	kcmil	mils	aluminum	copper
240	474	709	0.03887	0.02343
300	592	807	0.03109	0.01868
400	789	909	0.02419	0.01461
500	987	1039	0.01881	0.01137
630	1243	1189	0.01458	0.00880
800	1579	1335	0.01141	0.00687
1000	1974	1492	0.00905	0.00547
1200	2368	1732*	0.00768	0.00469
1600	3158	2047*	0.00578	0.00351
2000	3947	2205*	0.00463	0.00280
2500	4934	2598*	0.00395	0.00224

* Segmented Cu conductor including tapes

Table 18

Cross section		Diameter approx.	Nominal d.c. resistance at 25°C, ohm/1000 ft **	
kcmil	mm²	mils	aluminum	copper
500	253	736	0.03540	0.02160
750	380	906	0.02360	0.01440
1000	507	1059	0.01770	0.01080
1250	633	1189	0.01410	0.00863
1500	760	1319	0.01180	0.00719
1750	887	1425	0.01010	0.00616
2000	1013	1496	0.00885	0.00539
2500	1267	1772*	0.00715	0.00436
3000	1520	1890*	0.00596	0.00363
3500	1773	2067*	0.00515	0.00314
4000	2027	2165*	0.00451	0.00275
1 ohm/1000 ft = 3.28 ohm/km				

* Segmented Cu conductor including tapes
** The maximum value can be 2% higher

Standards – IEC and ICEA

Conductors are manufactured according to the following standards:

IEC (International Electrotechnical Commission) Standard Publication 60228, Class 2: Stranded circular or shaped conductors of copper or aluminum.

ICEA Standard Publication No. S-108-720, further specified in ASTM B 400 for aluminum and ASTM B 496 for copper.

Conductor water sealing

If required, the conductor can be water sealed by:

- Swelling material between the conductor strands. This material turns into jelly when in contact with water.
- Filling compound between the conductor strands.

XLPE CABLE DESIGN

Insulation

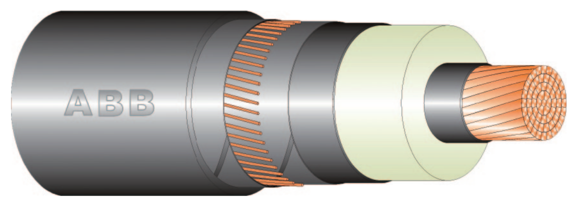
Conductor shield
The conductor shield consists of an extruded layer firmly bonded to the XLPE insulation. A very smooth material is used to obtain good electrical performance.

XLPE insulation
The XLPE insulation is extruded simultaneously with the conductor shield and the insulation shield, i.e. triple extrusion. The interface surfaces between insulation and conductive shields are not exposed at any stage during the manufacturing. High quality material-handling systems, triple extrusion, dry curing and super-clean XLPE materials guarantee high quality products. The insulation thickness is determined by the design electrical stresses for AC or DC impulse voltages. The actual thickness for different voltage levels and conductor sizes is given in Tables 19 to 23.

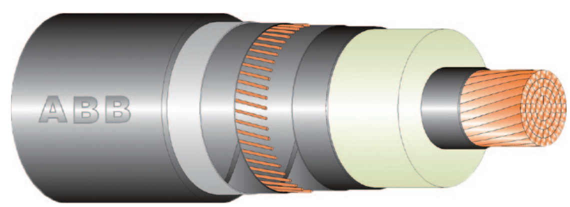
Insulation shield
This shield consists of an extruded layer firmly bonded to the XLPE insulation. The material is a high quality conductive compound. The interface between the shield and the insulation is smooth.

Metallic shield

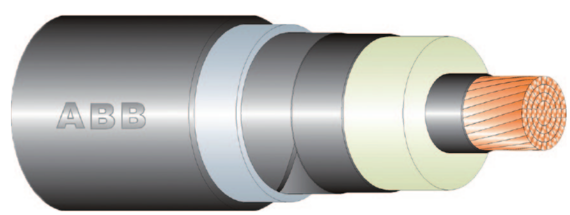
Copper wire shield, standard design
A polymeric jacket covers the copper wire shield.



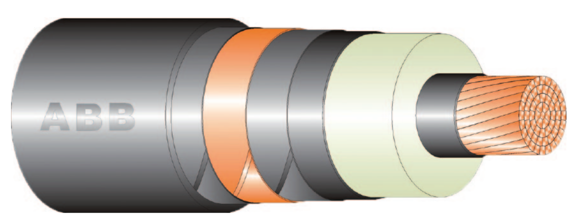
Copper wire shield, water tight design
Radial water sealing is achieved by using a metal-PE laminate. The metal is normally aluminum. Copper may also be used. The laminate is bonded to the polyethylene, which gives excellent mechanical properties. Longitudinal water sealing is achieved by using a water swelling material on either side of the copper wires or swelling powder between the shield wires.



Lead sheath
Radial water sealing is achieved by an extruded corrosion resistant lead sheath. Longitudinal water sealing is achieved by using a water swelling material applied under the lead sheath.



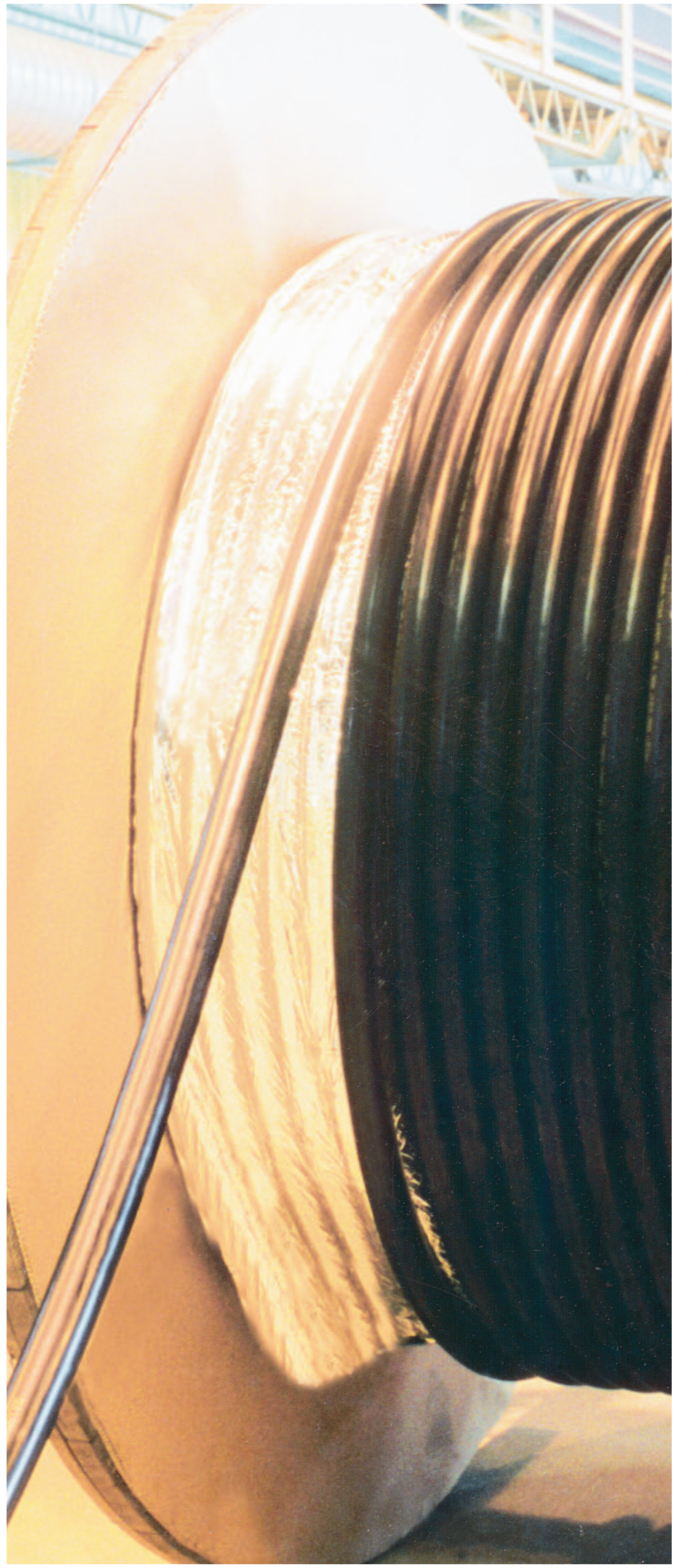
Copper tape shield
Cross section defined by the geometrical cross section of the copper tapes.



XLPE CABLE DESIGN

Non-metallic outer jacket

PE or PVC are normally used for the non-metallic outer jacket. ICEA S-108-720 specifies minimum point jacket thickness. Also, IEC 60502 recommends a thickness of $t = 0.035 \times D + 1.0$ mm, where D is the diameter under the jacket. For heavy installations a larger thickness is recommended. PE is the first choice for most applications. PVC is used when there are high requirements on fire retardation.



Conductive outer layer

A conductive outer layer facilitates testing of the non-metallic outer jacket. This testing is important to ensure the physical integrity of the cable from time to time, either in factory, after transportation, directly after laying, upon completion of the installation, or periodically thereafter.

A conductive outer layer obtained by simultaneous extrusion with the non-conductive outer jacket presents superior electrical and structural properties.

Flame retardant outer layer

For PE-jacketed cables a halogen free and flame retardant layer can be applied in order to limit the fire spread in buildings and tunnel installations.

Fire behavior

This relates to cables installed in buildings and tunnels.

Several serious fire accidents have focused attention on the fire behavior of cables. Experience shows that cables seldom initiate fires. However, in some cases cable installations have influenced the extent of a fire, as a propagator of flames and/or as a source of intense, aggressive smoke.

Cables having a PVC jacket are considered flame retardant. However, once PVC is on fire, it generates hydrochloric acid fumes (HCl). This gas is highly corrosive and irritating to inhale. Cables with a standard PE outer jacket do not generate any corrosive HCl, but are not flame retardant. Special polyolefins with flame retardant properties but without chlorine or any other halogens are optional for the outer jacket.

TECHNICAL DATA FOR XLPE AC LAND CABLE SYSTEMS

Cross-section of conductor	Diameter of conductor	Insulation thickness	Diameter over insulation	Cross-section of shield	Outer diameter of cable	Cable weight (Al-conductor)	Cable weight (Cu-conductor)	Capacitance	Charging current per phase at 60 Hz	Inductance ∴	Inductance •••	Surge impedance
kcmil	mils	mils	inches	kcmil	inches	lbs/ft	lbs/ft	µF/1000 ft	A/1000 ft	mH/1000 ft	mH/1000 ft	Ω
Table 19												
Single-core cables, nominal voltage 69 kV (U_m = 72.5 kV)												
500	736	354	1.54	180	2.14	2.15	3.21	0.069	1.03	0.122	0.224	28.5
750	906	354	1.71	180	2.32	2.54	4.13	0.079	1.19	0.115	0.212	24.8
1000	1059	354	1.88	180	2.50	2.93	5.05	0.089	1.34	0.110	0.202	22.2
1250	1189	354	2.01	180	2.65	3.31	5.96	0.097	1.46	0.106	0.195	20.5
1500	1319	354	2.14	180	2.80	3.68	6.86	0.105	1.58	0.103	0.189	19.0
1750	1425	354	2.27	180	2.94	4.06	7.77	0.113	1.70	0.102	0.184	17.9
2000	1496	354	2.34	180	3.01	4.35	8.59	0.117	1.76	0.100	0.181	17.3
2500	1703	354	2.58	180	3.27	5.00	10.52	0.132	1.98	0.097	0.173	15.7
3000	1854	354	2.73	180	3.43	5.61	12.20	0.141	2.11	0.095	0.168	14.7
3500	1988	354	2.86	180	3.58	6.16	13.97	0.149	2.23	0.093	0.164	13.9
4000	2126	354	3.00	180	3.74	6.86	15.60	0.157	2.36	0.092	0.160	13.2
Table 20												
Single-core cables, nominal voltage 115 kV (U_m = 123 kV)												
750	906	551	2.10	180	2.74	3.17	4.76	0.057	1.43	0.125	0.212	32.3
1000	1059	512	2.19	180	2.84	3.47	5.59	0.067	1.69	0.118	0.202	27.9
1250	1189	512	2.32	180	2.99	3.88	6.53	0.073	1.82	0.114	0.195	25.8
1500	1319	512	2.45	180	3.13	4.27	7.45	0.078	1.96	0.110	0.189	24.0
1750	1425	512	2.58	180	3.28	4.69	8.41	0.084	2.10	0.108	0.184	22.7
2000	1496	512	2.65	180	3.35	5.00	9.24	0.087	2.17	0.107	0.181	21.9
2500	1703	512	2.89	180	3.61	5.69	11.27	0.097	2.43	0.103	0.173	20.0
3000	1854	512	3.04	180	3.78	6.37	13.00	0.103	2.58	0.101	0.168	18.8
3500	1988	512	3.18	180	3.93	6.95	14.76	0.109	2.72	0.099	0.164	17.9
4000	2126	512	3.31	180	4.07	7.65	16.42	0.115	2.87	0.097	0.160	17.0
4934	2354	512	3.54	180	4.31	8.74	19.64	0.124	3.11	0.094	0.153	15.7
Table 21												
Single-core cables, nominal voltage 138 kV (U_m = 145 kV)												
750	906	630	2.26	180	2.91	3.46	5.05	0.052	1.56	0.129	0.212	34.9
1000	1059	591	2.35	180	3.00	3.76	5.88	0.061	1.82	0.121	0.202	30.4
1250	1189	591	2.48	180	3.17	4.20	6.85	0.065	1.97	0.117	0.195	28.2
1500	1319	591	2.61	180	3.30	4.60	7.78	0.070	2.11	0.113	0.189	26.3
1750	1425	591	2.74	180	3.44	5.03	8.74	0.075	2.25	0.111	0.184	24.9
2000	1496	591	2.81	180	3.52	5.36	9.60	0.078	2.33	0.110	0.181	24.1
2500	1703	591	3.05	180	3.79	6.09	11.65	0.086	2.60	0.106	0.173	22.0
3000	1854	591	3.20	180	3.95	6.77	13.41	0.092	2.76	0.104	0.168	20.7
3500	1988	591	3.33	180	4.09	7.34	15.18	0.097	2.91	0.101	0.164	19.7
4000	2126	591	3.47	180	4.24	8.06	16.85	0.102	3.06	0.100	0.160	18.7
4934	2354	591	3.70	180	4.49	9.19	20.12	0.110	3.31	0.097	0.153	17.3

TECHNICAL DATA FOR XLPE AC LAND CABLE SYSTEMS

Table 22

Cross-section of conductor	Diameter of conductor	Insulation thickness	Diameter over insulation	Cross-section of shield	Outer diameter of cable	Cable weight (Al-conductor)	Cable weight (Cu-conductor)	Capacitance	Charging current per phase at 60 Hz	Inductance		Surge impedance
kcmil	mils	mils	inches	kcmil	inches	lbs/ft	lbs/ft	μF/1000 ft	A/1000 ft	mH/1000 ft	mH/1000 ft	Ω
Single-core cables, nominal voltage 230 kV (U_m = 245 kV)												
1000	1059	945	3.08	500	3.86	6.45	8.57	0.045	2.23	0.136	0.202	40.1
1250	1189	906	3.13	500	3.94	6.77	9.42	0.049	2.46	0.130	0.195	36.7
1500	1319	906	3.26	500	4.07	7.23	10.41	0.052	2.62	0.126	0.189	34.4
1750	1425	906	3.37	500	4.19	7.66	11.37	0.055	2.75	0.123	0.184	32.7
2000	1496	906	3.44	500	4.27	8.02	12.26	0.057	2.84	0.121	0.181	31.7
2500	1703	906	3.68	500	4.52	8.79	14.41	0.062	3.13	0.117	0.173	29.1
3000	1854	906	3.83	500	4.69	9.54	16.24	0.066	3.31	0.114	0.168	27.5
3500	1988	906	3.96	500	4.82	10.15	18.09	0.069	3.47	0.112	0.164	26.2
4000	2126	906	4.10	500	4.97	10.95	19.81	0.073	3.64	0.109	0.160	25.0
4934	2354	906	4.33	500	5.22	12.16	23.20	0.078	3.91	0.106	0.153	23.3

Table 23

Single-core cables, nominal voltage 345 kV (U_m = 362 kV)												
1250	1189	1102	3.53	500	4.36	7.83	10.48	0.043	3.24	0.137	0.195	41.0
1500	1319	1102	3.66	500	4.50	8.33	11.51	0.046	3.44	0.132	0.189	38.5
1750	1425	1063	3.69	500	4.53	8.54	12.26	0.049	3.70	0.128	0.184	36.0
2000	1496	1024	3.68	500	4.52	8.69	12.93	0.052	3.91	0.125	0.181	34.2
2500	1703	984	3.84	500	4.69	9.27	14.90	0.059	4.42	0.119	0.173	30.6
3000	1854	984	3.99	500	4.85	10.01	16.73	0.062	4.67	0.116	0.168	29.0
3500	1988	984	4.12	500	5.00	10.65	18.62	0.065	4.90	0.114	0.164	27.7
4000	2126	984	4.26	500	5.14	11.45	20.35	0.068	5.13	0.111	0.160	26.4
4934	2354	984	4.49	500	5.39	12.68	23.74	0.073	5.51	0.108	0.153	24.6

FORMULAS

Formula for capacitance

$$C = \frac{\varepsilon_r}{59 \cdot \ln\left(\frac{r_o}{r_i}\right)} \ [\mu F/1000\ ft]$$

Where ε = relative permittivity of the insulation
r_o = external radius of the insulation (inches)
r_i = radius of conductor, including shield (inches)
ε_r XLPE = 2.5 (Value from IEC 60287)

Formula for dielectric losses

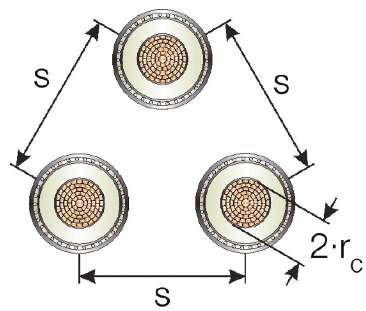
$$W = \frac{V^2}{3} 2\pi f \cdot C \cdot \tan(\delta) \ [W/1000\ ft]$$

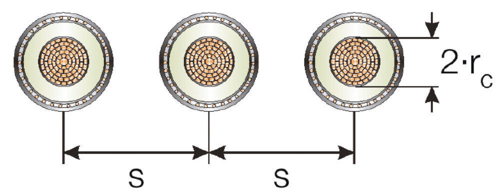
Where V = rated (phase-to-phase) voltage (kV)
f = frequency (Hz)
C = capacitance (μF/1000 ft)
tan δ = loss angle

Formula for inductance

$$L = 0.0152 + 0.061 \cdot \ln\left(\frac{K \cdot s}{r_c}\right) \ [mH/1000\ ft]$$

Where trefoil formation: K = 1
flat formation: K = 1.26
s = distance between conductor axes (inches)
r_C = conductor radius (inches)





Formula for inductive reactance

$$X = 2\pi f \cdot \frac{L}{1000} \ [\Omega/1000\ ft]$$

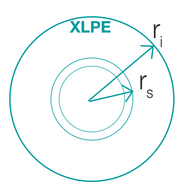
Where f = frequency (Hz)
L = inductance (mH/1000 ft)

Formula for electric stress

Conductor shield: $$G_{max} = \frac{V_g}{r_s \ln\left(\frac{r_i}{r_s}\right)} \ [V/mil]$$

Insulation shield: $$G_{min} = \frac{V_g}{r_i \ln\left(\frac{r_i}{r_s}\right)} \ [V/mil]$$

r_s = radius of conductor shield (mils)
r_i = radius of XLPE insulation (mils)
V_g = phase-to-ground voltage (volts)



Formula for maximum short circuit currents

$$I_{sh} = \frac{I_1}{\sqrt{t_{sh}}} \ [kA]$$

I_{sh} = short-circuit current during time tsh
I_1 = short-circuit current rating during 1 second.
See the 1 second value in tables 11 for the conductor and in Table 12 for the metallic shield.
t_{sh} = short-circuit duration (sec)

For XLPE insulated conductors the maximum allowable short circuit temperature is 250ºC.

Formula for calculation of dynamic forces between two conductors

$$F = \frac{0.53}{S} \cdot I_{peak}^2 \ [lbf/ft]$$

Where; I_{peak} = 2.5 Ish [kA]
I_{sh} = short-circuit current [kA] RMS
S = center to center spacing between conductors [inches]
F = maximum force [lbf/ft]

SUPPORT

The transmission network in most countries is very large and complex. It may incorporate many different types of transmission circuits including AC and DC over-head lines, fluid-filled cable systems, extruded cable systems, etc. Many modern networks contain extensive land and submarine cable systems for supply of major metropolitan areas and for interconnection with neighboring countries.

ABB's experienced project managers, technical specialists and other staff will give their professional support in evaluating suitable solutions. We aim to offer the most optimal solution and we can supply the complete land or submarine cable system, which can include:

- Power cables for land or submarine applications
- Cable accessories
- Control- and telecommunication cables
- System design for network optimization
- Project management
- Civil works
- Installation and supervision
- Testing and start-up operations
- Disassembly and recovery of old cables
- Fault localization and cable repair
- Maintenance of fluid-filled systems
- Leasing of installation equipment
- Training

NOTE: All data given in this brochure is non-binding and indicative only

CHECKLIST FOR CABLE INQUIRY

ABB is always prepared to work closely with our customers to develop optimized and cost effective cable system design solutions. In order for us to identify the best overall design solution for a specific application, we kindly request that the below data checklist is submitted with each inquiry (if some of the requested data is not available at the time of the inquiry, or does not appear applicable, just insert “N/A” in the corresponding data cell).

Commercial information

* Required information

Name of project	*
Customer	*
Location of site for delivery	*
Inquiry for budget or purchase	*
Tender submission date	*
Do any special conditions apply	
How long should the tender be valid	*
Required delivery/completion time	*
Terms of delivery (FCA/CPT etc.)	*
Specific requirements on cable length per delivered reel	
Do any specific metal prices apply	
Installation: Turnkey by ABB Installation by ABB Supervision by ABB	*

Technical information

* Required information

Cable system input		
Maximum system voltage V_{max}	*	kV
Nominal system operating voltage V	*	kV
Continuous current / power capacity	*	A/MVA
Operating frequency	*	Hz
Maximum symmetrical short-circuit current and duration	*	kA/s
Maximum earth-fault current and duration	*	kA/s
Route length	*	ft
Conductor: copper/aluminum, cross-section		Cu/Al, kcmil
Longitudinal water protection	*	Yes/No
Radial water protection	*	Yes/No
Any special cable design requirements Customer specification		

Tests

Routine, sample and after installation test. IEC, AEIC, ICEA, other
Type test requirements. IEC, AEIC, ICEA, other
Other test requirements

Installation data

* Required information

Cable configuration: Flat/Trefoil	
Number of parallel circuits *	
Distance between parallel circuits	inch
Heating from existing cables	Yes/No
If yes, distances to and losses of parallel cables	inch, W/ft
Other heat sources, distance to and losses of sources	inch, W/ft
Shield earthing (Both ends, Cross, Single)	

* Required information

Installed in air	*	Yes/No
Air temperature, maximum		°C
Installed in trough		Yes/No
If trough, inside dimension of trough (width x height)		inch x inch
If trough, filled or unfilled		
Exposed to solar radiation		Yes/No
Direct buried installation	*	Yes/No
Soil, ground temperature at laying depth		°C
Laying depth		inch
Thermal resistivity backfill		°C•cm/W
If drying out, thermal resistivity of dry backfill close to cable		°C•cm/W
Backfill material: selected sand, CBS, etc		
Special requirements for trench		
Load factor		%
Cables in ducts or pipes, buried ducts	*	Yes/No
Material: PVC, PE, fiber, steel, etc.		
Distance between ducts/pipes		inch
Inside and outside pipe diameter		inch, inch
Duct height and width		inch, inch
Ambient temperature at burial depth		°C
Thermal resistivity of ground		°C•cm/W
Thermal resistivity of backfill		°C•cm/W
If drying out, thermal resistivity dry backfill close to duct		°C•cm/W
Laying depth		inch
Backfill material: selected sand, CBS, etc.		
Load factor		%

Accessories

* Required information

Termination	
Type of termination and quantity. Indoor, outdoor, AIS, GIS, transformer, etc.	Type * Qty *
Special requirements - pollution level, rod gap, polymer insulator, etc.	
Joints	
Type of joint and quantity - premolded, vulcanized, sectionalized, straight, etc.	Type * Qty *
Special requirements	
Link boxes	
Type of link box	
Special requirements	
Other accessories	
Other relevant information	

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