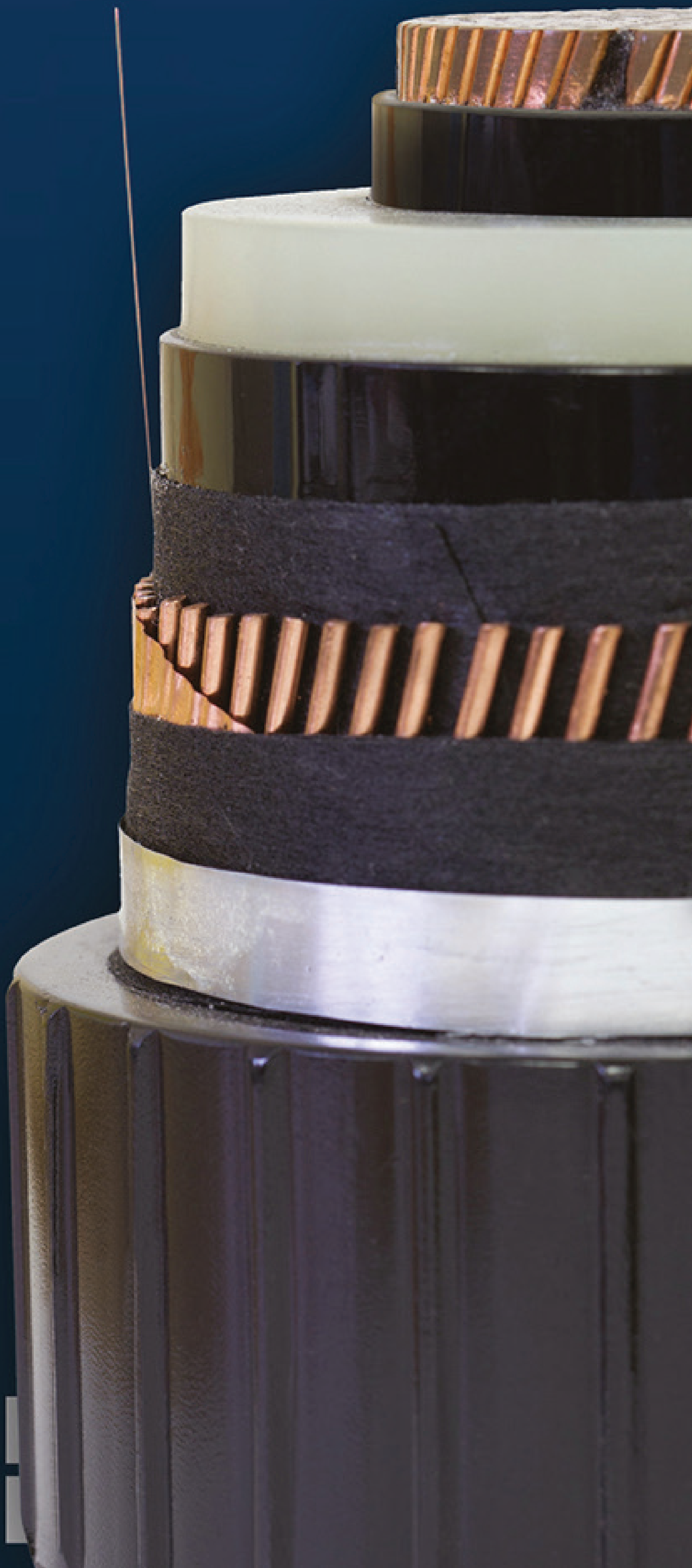
ESTRALIN HVC

POWER CABLES AND CABLE SYSTEMS 6-220 KV

MODERN SOLUTIONS
FOR POWER CABLES



Cables 6-35 kV and 110-220 kV are widely used for electric energy transmission and distribution especially in large cities and at production plants, where electric energy consumption and load density levels are particularly high. Although basic requirements to cables (i.e. reliability, functionality, low costs of maintenance) are obvious they should be thoroughly met because their violation can cause considerable financial losses.

Cable's service life should be long; their function is to provide continuously the consumer with sufficient amount of electric power. Unlike cables with paper-filled or oil-filled insulation that find limited use from year to year, cables with cross-linked polyethylene insulation (Russian designation is – СПЭ, English – XLPE, German-VDE, and Swedish - PEX) meet that requirement in full.

Medium and high voltage XLPE cables due to the design, modern production technology and perfect materials have better electric and mechanical properties and the longest service life among other types of cables of mass production.

XLPE cables transfer capability is substantially higher than that of cables with paper or oil-filled insulation. According to international standards procedure, the cable is designed for continuous service with conductor temperature of 90°C and it is still active under emergency conditions even at higher temperatures, while oil-filled with paper insulation cables can withstand heating only to 70°C.

Advantage of XLPE cable is its environmental safety. Absence of liquid inclusions ensures maintaining clean environment, which permits its laying at any projects and service-free maintenance of cable lines.

Due to its single core design, cable laying is easier, as well as the installation accessories, even in the most extreme conditions. Cable laying is still possible at temperatures up to -20°C with polyethylene cable sheath.

XLPE cable production technology was first introduced in the 70s of XX century. The cross-links are a space lattice constructed using formation of longitudinal and transversal ties between macromolecules of polymer. With its physical and electrical properties, cross-linked polymer suits ideally for insulation of medium, high and extra-high voltage cables.

During production of XLPE cable a special attention is paid on the purity and quality of insulating materials, as any inclusions released to the insulation reduces the life of the cable. It is for this reason, the concept of clean rooms, excluding ingress of foreign particles, as well as interaction with reliable suppliers of high quality raw materials, are one of the foundations of the production of reliable cable with a long trouble-free operation time.

It should be stressed that insulation and electrically conducting screens are applied in the process of triple extrusion followed with the simultaneous cross-linking of all three layers. Such a technology ensures high adhesion between the screens and insulation.

Advantages of the enhanced design and modern production technology of XLPE cables have determined their universal application in developed countries and notable decrease in the use of other type cables.

Estralin HVC – a pioneer in Russia's XLPE cable production

The aim of the plant "Estralin High Voltage Cables" (Estralin HVC) is introduction of innovative technologies in the field of power cable production. Providing high-quality production and services, we are helping our customers to raise their competitiveness and reduce the adverse impact upon environment.

Estralin HVC pays attention to technologies development and advancement that provide high quality of manufactured products. Only best materials of leading world manufacturers are used for cable insulation. These are peroxide-cross-linked polyethylenes, triingostable (TSPE) and copolymer (CCPE) polyethylenes. High skilled personnel and the use of high-quality basic materials are the key to perfect production that complies the requirements of advanced Russian and international standards and equals its West-European counterparts.

Continuous control over all phases of the process, starting with the choice of cable and accessories at the design stage and up to commissioning of completed cable line, permits the Company fully satisfy customer's requirements to modern cable lines. A systematic approach of complying international quality standards has been introduced at the factory.

High emphasis is placed upon environmental aspects of the production. Estralin HVC's successes in development and introduction of quality assurance systems and environmental management have been recognized by the largest independent European certification Company, TUV CERT: the Plant was awarded certificates of conformity with regulatory requirements ISO 9001 : 2008.

Main types of products and services

A main activity of Estralin HVC is XLPE cable 6-220 kV production, which use in insulated or earthed networks.

All cables, by their design, technological data and service characteristics comply the international standard requirements: IEC 60502-2 (6-35 kV cables), IEC 60840 (110 kV cables), and IEC 62067 (220 kV cables), as well as with the GOST R certification, including those with regard to fire safety.

Our company offers:

– medium and high voltage cable accessories;

– technical support at all stages of cooperation.

Markings

Conductor material	**Without designation**	Copper conductor
	A	Aluminum conductor
	RMS	Segmented conductor
Insulation material	Y	PVC insulation
	2XS	XLPE insulation
Screen	S	Copper wire and copper tape screen
	SE	Copper wire and copper tape screen around each cable conductor
	(F)	Watertight screen from swelling tape which provides longitudinal water sealing
	(FL)	Watertight screen from swelling tape which provides longitudinal water sealing and laminated polymer
Armouring	F	Wires armouring from galvanized steel
	G	Armouring: tape from galvanized steel winding with 2 spirals in the opposite directions
	B	Armouring from double steel tape
	R	Armouring from galvanized steel wire of coaxial shape
Sheath	K	Lead sheath
	Y	PVC sheath
	2Y	XLPE sheath
	H	Halogen free flame retardant sheath
	LWL (following screen designation)	Optic fibers in steel tubing inserted into copper

Example[1]:

A2XS(FL)Y-A-LWL 1x1600RMS/185 64/110 kV

- A — Aluminum conductor
- 2XS — XLPE insulation
- (FL)Y-A — Dual water sealed, flame retardant PVC outer sheath of category «A»
- LWL — Integrated optical fiber
- 1x — Conductor quantity
- 1600RMS — Longitudinal segmented conductor
- /185 — Screen cross-section
- 64/110 — Nominal voltage

1 Cable design and markings can be changed when new decisions are implemented.

Comparative characteristics	6-35 kV XLPE-cables	Paper-insulated cables	
		10 kV	20-35 kV
Continuous permissible temperature, °C	90	70	65
Permissible heating in emergency, °C	130	90	65
Maximum permissible temperature under short-circuit current flow, °C	250	200	130
Minimum cable laying temperature without pre-heating, °C	-20	0	0
Relative permittivity ε at 20°C	2,4	4,0	4,0
Dielectric loss ratio tg δ at 20°C	0,001	0,008	0,008
Level differential at cable laying operation, m	not limited	15	15

Main advantages of XLPE-cables are:

- big cable transmission capability due to increased conductor permissible temperature (permissible load currents are 15-30% higher than those of paper-insulated cables, depending on cable laying conditions);
- high-current thermal stability at short circuit that is of a special importance when a cross-section has been chosen on the basis of short-circuit nominal current only;
- light-weight, smaller diameter and bending radius, which facilitates cable laying in both cable structures and underground along complicated routes;
- feasibility of cable laying at temperatures up to - 20°C without preheating due to the use of polymer materials in insulation and screening;
- low specific damageability (practice of XLPE-cables employment demonstrates that their damage resistance at least is 1-2 orders lower than that of paper-insulated and cables);
- absence of any liquid components (oils), and therefore, time and cost of cable laying and installation is reduced;
- single-core design permits cable to produce with a conductor with cross-section up to 1000 mm2 that is optimal for a large-power transmission;
- large lengths for construction: up to 2000-4000 m.

Take into account that the main type of single core cable faults are single-phase short circuit; it is possible to confirm that repair costs are drastically cut.

Strong insulation provides enormous advantages at the cable laying over a sloping, hilly or rough terrain, i.e. along the routes with considerable level difference, in vertical and inclined collectors.

Design

6, 10, 20 and 35 kV XLPE cable consists of a round copper or aluminum stranded conductor, a semiconductive layer over the conductor, a cross-linked polyethylene insulation, a conductive layer on the insulation, a conductive tape, a screen of cooper wires and a copper band, a separating layer, a high-density polyethylene sheathing, and a PVC plasticate sheathing or PVC plasticate sheath of reduced combustibility with reduced smoke and gas emission, or a sheath of halogen-free polyethylene composite.

In order to ensure the screen longitudinal sealing, a water-blocking conductive tape can be used in place of a conductive tape, and a water-blocking conductive tape layer can replace a separation layer.

Cables indexed «FL» are provided with an alumo-polymer tape sheath welded to the polyethylene or PVC sheath apart from having longitudinal sealing. Such a design creates an effective diffusion barrier stopping penetration of water vapors; and an outside sheath of black polyethylene provides protection against mechanical damage.

Field of application

2XS2Y, A2XS2Y, cables are used for underground lines for complicated sections of the routes, as well as for overhead lines providing proper fire protection. Cables with longitudinal sealing could be used for underground lines in humid soils and in damp, partially flooded premises.

2XSY, A2XSY, 2XS(FL)Y, and A2XS(FL)Y cables are used for cable structures and industrial premises (2XS(Fl)Y and A2XS(Fl)Y – in batch laying), and also underground in dry soils.

2XS(FL)Y-LS and A2XS(FL)Y-LS cables are intended for stationary overhead batch lines, in cable structures and premises that have specified limitation on smoke consistency in fire situations.

2XS(Fl)Y-HF and A2XS(Fl)Y-HF are used for stationary electrical installations inside public and industrial buildings limited by requirements restricting impact of corrosive gases.

6-10 kV[1] XLPE cable specifications

Nominal cross-section	mm²	50	70	95	120	150	185	240	300	400	500	630	800	1000	1200
Screen cross-section[2]	mm²	16	16	16	16	25	25	25	25	35	35	35	35	35	50
Insulation thickness	mm	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4
Sheath thickness	mm	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,7	2,7	2,9	2,9
D outside[3]	mm	27,4	29,1	30,8	32,3	33,5	35,4	37,6	39,9	42,9	45,9	49,8	54	58,2	63,4
Weight approx.[3] Al conductor	kg/km	689	784	891	994	1189	1329	1529	1746	2173	2512	2981	3543	4210	5152
Cu conductor		999	1217	1479	1737	2117	2473	3014	3602	4647	5606	6894	8492	10397	12781
Min. bending radius	cm	42	44	47	49	51	53	57	60	65	69	75	81	87	95
Permissible pulling force Al conductor	кN	1,5	2,1	2,85	3,60	4,50	5,55	7,20	9,00	12,0	15,0	18,9	24,0	30,0	36,0
Cu conductor		2,5	3,5	4,75	6,00	7,50	9,25	12,0	15,0	20,0	25,0	31,5	40,0	50,0	60,0
Max. single length supply [4]	m	11760	10380	9150	8550	7810	7090	6410	5810	5270	4760	4290	3790	3410	3050
Continuous permis. earth current[3] Cu	A	223	273	326	370	414	467	540	607	683	768	858	947	1026	1060
Al		173	212	253	288	322	365	423	477	543	618	702	788	871	920
Continuous permis. earth current[3] Cu	A	231	282	336	379	421	472	542	606	662	736	814	889	957	945
Al		180	220	262	296	331	373	431	484	540	609	683	759	833	846
Continuous permis. air current[3] Cu	A	259	322	391	450	509	581	683	782	899	1030	1175	1327	1452	1541
Al		201	250	304	350	396	454	535	614	715	829	959	1102	1230	1334
Continuous permis. air current[3] Cu	A	301	374	454	522	582	662	771	875	969	1090	1222	1355	1497	1501
Al		234	292	355	409	458	525	615	702	796	909	1036	1170	1308	1351

1 All data in Table 1 apply for categories A and B networks (acc. to IEC 60183).

2 Cross-section of the screen shown in the Table is minimal. Cross-section of the screen is chosen under condition of short-circuit current .

3 Weight, outside diameter and continuous permissible cable currents are for cable types 2XS2Y и A2XS2Y with minimal cross-section of the screen. If a larger screen cross-section is desired, continuous permissible cable currents get lower because of increased losses in the screen.

4 Deviation from the nominal construction length is ± 1%.

20 kV XLPE cable specifications

Nominal cross-section	mm²	50	70	95	120	150	185	240	300	400	500	630	800	1000	1200
Screen cross-section[1]	mm²	16	16	16	16	25	25	25	25	35	35	35	35	35	50
Insulation thickness	mm	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5
Sheath thickness	mm	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,7	2,7	2,9	2,9	2,9
D outside[2]	mm	31,6	33,3	34,9	36,4	37,7	39,6	41,8	44,1	47,5	50,5	54,0	58,6	62,4	67,6
Weight approx.[2] **Al conductor**	kg/km	849	953	1073	1185	1386	1537	1751	1981	2455	2815	3277	3899	4557	5568
Weight approx.[2] **Cu conductor**	kg/km	1158	1386	1660	1927	2314	2681	3236	3838	4930	5908	7192	8848	10744	13197
Min. bending radius	cm	48	50	52	55	57	60	63	66	72	76	si	88	94	101
Permissible pulling force **Al conductor**	кN	1,5	2,1	2,85	3,60	4,50	5,55	7,20	9,00	12,0	15,0	18,9	24,0	30,0	36,0
Permissible pulling force **Cu conductor**	кN	2,5	3,5	4,75	6,00	7,50	9,25	12,0	15,0	20,0	25,0	31,5	40,0	50,0	60,0
Max. single length supply[3]	m	8380	7500	6670	6250	5770	5260	4790	4370	3990	3620	3260	2910	2640	2370
Continuous permis. earth current[2] (trefoil) **Cu**	A	224	274	327	371	416	469	542	610	687	774	869	961	1040	1073
Continuous permis. earth current[2] (trefoil) **Al**	A	174	213	254	289	323	366	424	479	545	621	706	794	879	928
Continuous permis. earth current[2] (flat) **Cu**	A	231	282	337	382	423	474	545	609	667	742	823	900	966	953
Continuous permis. earth current[2] (flat) **Al**	A	180	220	262	298	332	374	432	485	543	612	688	765	839	852
Continuous permis. air current[2] (trefoil) **Cu**	A	261	325	394	453	512	585	687	786	903	1036	1182	1336	1468	1555
Continuous permis. air current[2] (trefoil) **Al**	A	203	252	306	352	398	457	537	616	717	830	960	1104	1236	1340
Continuous permis. air current[2] (flat) **Cu**	A	298	371	450	517	577	657	764	868	965	1088	1221	1359	1500	1509
Continuous permis. air current[2] (flat) **Al**	A	232	289	351	404	454	519	608	694	788	902	1028	1165	1304	1352

1 Cross-section of the screen shown in the Table is minimal. Cross-section of the screen is chosen under condition of short-circuit current.

2 Weight, outside diameter and continuous permissible cable currents are for cable types 2XS2Y и A2XS2Y with minimal cross-section of the screen. If a larger screen cross-section is desired, continuous permissible cable currents get lower because of increased losses in the screen.

3 Deviation from the nominal construction length is ± 1%.

35 kV XLPE cable specifications

Nominal cross-section	mm²	50	70	95	120	150	185	240	300	400	500	630	800	1000	1200
Screen cross-section[1]	mm²	16	16	16	16	25	25	25	25	35	35	35	35	35	50
Insulation thickness	mm	9,0	9,0	9,0	9,0	19,0	2,5	9,0	9,0	9,0	9,0	9,0	9,0	9,0	9,0
Sheath thickness	mm	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,7	2,7	2,9	2,9	2,9	2,9	2,9
D outside[2]	mm	38,2	39,9	41,6	43,1	44,7	46,7	49,3	51,6	55,0	58,0	61,4	65,6	69,4	74,6
Weight approx.[2] **Al conductor**	kg/km	1171	1293	1428	1556	1770	1948	2214	2470	2980	3371	3863	4495	5162	6324
Cu conductor	kg/km	1480	1726	2016	2298	2698	3093	3699	4326	5455	6465	7781	9445	11379	13953
Min. bending radius	cm	57	59	63	65	67	70	74	78	83	87	92	99	104	112
Permissible pulling force Al conductor	кN	1,5	2,1	2,85	3,60	4,50	5,55	7,20	9,0	12,0	15,0	18,9	24,0	30,0	36,0
Cu conductor	кN	2,5	3,5	4,75	6,0	7,50	9,25	12,0	15,0	20,0	25,0	31,5	40,0	50,0	60,0
Max. single length supply[3]	m	7690	6990	6290	5950	520	5100	4670	4350	3950	3610	3280	2510	2700	2430
Continuous permis. earth current[2] (trefoil) **Cu**	A	224	274	327	371	1416	469	542	610	687	774	869	961	1040	1091
Al	A	174	213	254	289	1323	366	424	479	545	621	706	794	879	939
Continuous permis. earth current[2] (flat) **Cu**	A	231	282	337	382	1423	474	545	609	667	742	823	900	966	965
Al	A	180	220	262	298	1332	374	432	485	543	612	688	765	839	861
Continuous permis. air current[2] (trefoil) **Cu**	A	261	325	394	453	512	585	687	786	903	1036	1182	1336	1468	1572
Al	A	203	252	306	352	398	457	537	616	717	830	960	1104	1236	1346
Continuous permis. air current[2] (flat) **Cu**	A	298	371	450	517	577	657	764	868	965	1088	1221	1359	1500	1520
Al	A	232	289	351	404	454	519	608	694	788	902	1028	1165	1304	1352

1 Cross-section of the screen shown in the Table is minimal. Cross-section of the screen is chosen under condition of short-circuit current.

2 Weight, outside diameter and continuous permissible cable currents are for cable types 2XS2Y и A2XS2Y with minimal cross-section of the screen. If a larger screen cross-section is desired, continuous permissible cable currents get lower because of increased losses in the screen.

3 Deviation from the nominal construction length is ± 1%.

XLPE cables 6-35 kV

Medium voltage cables load capacity is calculated for the following conditions:

Laid in ground:

load factor	1,0
depth of cable laying	0,7 m
soil thermal resistance	1,2 K•m/W
ambient temperature, t°	15°C
conductor temperature, t°	90°C

Laid in air

load factor	1,0
ambient temperature, t°	25°C
conductor temperature, t°	90°C

Continuous permissible currents are fixed for each cable line under service conditions with regard to specific requirements. At different design ambient temperatures, it is advised to use corrective ratios, given in the following Table.

When single-core cables are fixed in triangle formation they are laid immediately adjacent. When single core cables are laid in flat formation, clear distance between them is one cable diameter.

Correction factors for ambient temperatutre

Temperatutre	-5	0	5	10	15	20	25	30	35	40	45	50
in ground	1,13	1,10	1,06	1,03	1,00	0,97	0,93	0,89	0,86	0,82	0,77	0,73
in air	1,21	1,18	1,14	1,11	1,07	1,04	1,00	0,96	0,92	0,88	0,83	0,78

Correction factors for specific soil resistance

Soil specific thermal resistance, K·m/W	0.8	1,0	1.2	1.5	2.0	2.5
Correction factor	1,13	1,05	1,00	0,93	0,85	0,8

Correction factors for the laying depth

Depth of cable laying, m	0,50	0,70	0,90	1,00	1,20	1,50
Correction factor	1,05	1,00	0,96	0,95	0,93	0,9

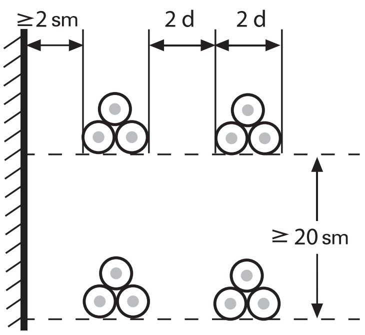
Correction factors on number of working cables arranged in plane side by side underground in pipes or without pipes, are used, when a section of a cable line between the earthing points is partially laid in pipes, under following conditions:

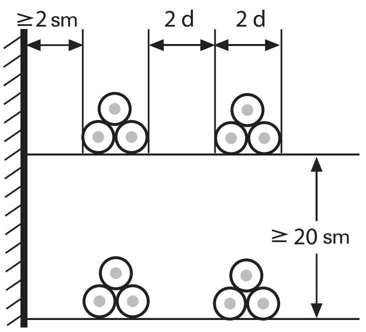
– cable are laid in a triangle formation over a substantial part of the line section;
– pipes are laid in flat formation;
– length of piping composes less than 10% of the section between the earthing points;
– each cable is laid in a separate pipe;
– pipe diameter is twice cable diameter.

Correction factors for side by side laying of the 6,10,15, 20 and 35 kV cables	
Cables partially laid in separate pipes	0,94
Cables in separate pipes on a plane	0,90
Single-conductor cables laid in triangle formation in a common pipe	0,90

Correction factors for group of cables in the ground

Clear distance between groups, mm	Number of groups				
	2	3	4	5	6
100	0,76	0,67	0,59	0,55	0,51
200	0,81	0,71	0,65	0,61	0,49
400	0,85	0,77	0,72	0,69	0,66





Correction factors for group of cables in air arranged in a triangle

Number of racks	Number of cables/systems on a rack		
	1	2	3
1	1,00	0,98	0,96
2	1,00	0,95	0,93
3	1,00	0,94	0,92
4-6	1,00	0,93	0,90
1	0,95	0,90	0,88
2	0,90	0,85	0,83
3	0,88	0,83	0,81
4-6	0,86	0,81	0,79

Short-circuit currents

Short-circuit current for all types of cables and cross-sections are calculated on the basis of the following conditions:

Conductor temperature		Screen temperature	
before short-circuit	90°C	before short-circuit	70°C
after short-circuit	250°C	after short-circuit	350°C

Permissible conductor one-second short-circuit current

Conductor cross-section mm²	50	70	95	120	150	185	240	300	400	500	630	800	1000	1200
Copper conductor	7,15	1,00	13,6	17,2	21,5	26,5	34,3	42,9	57,2	71,5	90,1	114,4	143,0	172,8
Aluminum conductor	4,7	6,6	8,9	11,3	14,2	17,5	22,7	28,2	37,6	47,0	59,2	75,2	93,9	114,3

Permissible screen one-second short-circuit current

Screen [1] cross-section mm²	16	25	35	50	70
1-sec. screen short-circuit current , KA	3,3	5,1	7,1	10,2	14,2

If short-circuit duration differs from 1 sec., short-circuit values shown in the Tables are multiplied by correction coefficient:

$K = 1/\sqrt{t}$, where t — short-circuit duration, sec

[1] Values of permissible short-circuit currents for different cross-sections of the screen are calculated on request.

Electrical specification

Conductor's DC resistance at 20°C, Ω/km, not less		
Nominal cross-section of conductor, mm²	Copper conductor	Aluminum conductor
50	0,3870	0,6410
70	0,2680	0,4430
95	0,1930	0,3200
120	0,1530	0,2530
150	0,1240	0,2060
185	0,0991	0,1640
240	0,0754	0,1250
300	0,0601	0,1000
400	0,0470	0,0778
500	0,0366	0,0605
630	0,0280	0,0464
800	0,0221	0,0367
1000	0,0176	0,0291
1200	0,0151	0,0247

Conductor resistance at temperatures, different from 20°C, is calculated with the formula:

for copper conductor:

$R_{\tau}=R_{20}\cdot(234{,}5+\tau)/254{,}5$

for aluminum conductor:

$R_{\tau}=R_{20}\cdot(228+\tau)/254{,}5$

where:

τ — conductor's temperature, (°C),

R_{20} — conductor resistance at 20°C, (Ω/km),

R_{τ} — conductor resistance at d°C, (Ω/km)

Cable capacitance for various voltage levels, μF/km														
Voltage, kV	Conductor cross-section, mm²													
	50	70	95	120	150	185	240	300	400	500	630	800	1000	1200
6	0,300	0,340	0,390	0,420	0,450	0,500	0,560	0,610	0,620	0,670	0,750	0,840	0,930	1,040
6/10	0,255	0,2891	0,328	0,351	0,384	0,423	0,468	0,516	0,569	0,630	0,700	0,792	0,880	0,983
10/10	0,226	0,254	0,288	0,307	0,336	0,370	0,410	0,450	0,493	0,550	0,610	0,680	0,757	0,845
15	0,207	0,230	0,262	0,280	0,305	0,325	0,369	0,405	0,445	0,492	0,548	0,615	0,680	0,759
20	0,179	0,200	0,225	0,240	0,260	0,285	0,313	0,343	0,376	0,414	0,460	0,515	0,568	0,633
35	0,130	0,143	0,159	0,168	0,181	0,196	0,214	0,230	0,253	0,277	0,305	0,399	0,371	0,411

Charging current for various voltage levels , A/km														
Voltage, kV	Conductor cross-section, mm^2													
	50	70	95	120	150	185	240	300	400	500	630	800	1000	1200
6	0,305	0,348	0,381	0,414	0,446	0,490	0,555	0,599	0,609	0,675	0,773	0,871	0,969	1,068
10	0,435	0,490	0,544	0,580	0,635	0,689	0,780	0,852	0,961	1,070	1,215	1,378	1,524	1,780
15	0,560	0,630	0,710	0,780	0,830	0,910	1,010	1,100	1,230	1,360	1,490	1,670	1,850	2,060
20	0,617	0,689	0,762	0,834	0,943	0,979	1,052	1,161	1,270	1,415	1,560	1,778	1,959	2,290
35	0,889	1,016	1,143	1,206	1,270	1,397	1,524	1,651	1,841	2,031	2,222	2,539	2,857	2,610

Conductor inductive reactance at frequency of 50 Hz[1], Ω/km						
Nominal conductor cross section,, mm^2	6/10[2] kV		20[2]kV		35[2] KV	
						
50	0,204	0,127	0,219	0,143	0,231	0,156
70	0,196	0,119	0,210	0,134	0,222	0,146
95	0,189	0,112	0,203	0,127	0,214	0,139
120	0,184	0,108	0,198	0,122	0,209	0,133
150	0,179	0,103	0,192	0,116	0,203	0,127
185	0,175	0,099	0,188	0,112	0,198	0,122
240	0,170	0,094	0,183	0,107	0,193	0,117
300	0,167	0,091	0,179	0,103	0,189	0,113
400	0,165	0,088	0,173	0,097	0,182	0,106
500	0,161	0,085	0,169	0,093	0,178	0,102
630	0,159	0,083	0,166	0,090	0,174	0,098
800	0,157	0,081	0,163	0,087	0,170	0,094
1000	0,154	0,079	0,159	0,083	0,166	0,090
1200	0,152	0,076	0,156	0,080	0,162	0,087

Calculation of inductive reactances are carried out with cables arranged in a triangle immediately adjacent, and in flat formation with clear distance between the cables equal to cable diameter.

1 Inductive values are calculated with regard to the screen earthing from both sides.

2 Inductive reactance values for other classes of voltage and another arrangement of cables are calculated on request.

Cable laying conditions and testing after medium voltage cable laying

Bending radius of XLPE cable during cable laying procedure shall be at least 15xD, where D — outside cable diameter. When cable accessories installation is carried out with the use of a special template minimal bending radius is permitted to be reduced down to template 7,5xD.

When installing with the use of a cable sleeve or taking by the conductor, pulling tension shall not exceed the following figures:

F=Sx50 N/ mm^2 — for copper conductor,
F=Sx30 N/ mm^2 — for aluminum conductor,
where S — conductor area of the cross-section, mm^2.

Cable temperature during installation shall be not lower than:

-15°C – for cables with PVC- plasticate sheath;
-20°C – for cables with polyethylene sheath.

This is achieved when keeping the cable in warm (about 20°C) premises during 48 hours or with the use of special equipment.

After cable laying and accessories installation it is recommended to conduct testing with the following AC voltage, frequency 0,1 Hz during 15 minutes:

10 kV cable with 18 kV,
15 kV cable with 45 kV,
20 kV cable with 60 kV,
35 kV cable with 105 kV voltage.

It is permissible to test with AC voltage of industrial frequency during 24 hours:

10 kV cable with 6 kV,
15 kV cable with 8,7 kV,
20 kV cable with 12 kV,
35 kV cable with 20 kV voltage.

On completing the installation and in coordination with cable manufacturing plant, cable testing is permitted with DC voltage of $4U_0$ during 15 minutes.

Cable sheath shall be tested with DC voltage of 10 kV, applied between the metallic screen and earthing device during at least 1 minute.

Capacity of cable drums

XLPE cable delivery length, m			
Cable outside diameter, mm	Construction length of cable, m		
	22D	24D	25D
26	2405	4566	6593
27	2230	4234	6113
28	2073	3937	5685
29	1933	3670	5299
30	1806	3430	4952
31	1692	3212	4638
32	1587	3014	4352
33	1493	2835	4092
34	1406	2670	3855
35	1327	2520	3638
36	1254	2382	3439
37	1187	2255	3255
38	1126	2138	3086
39	1069	2029	2930
40	1016	1929	2785
41	967	1836	2651
42	922	1750	2526
43	879	1669	2410
44	840	1594	2302
45	803	1524	2201
46	768	1459	2106
47	736	1397	2018
48	706	1340	1934

XLPE cable delivery length, m			
Cable outside diameter, mm	Construction length of cable, m		
	22D	24D	25D
49	677	1286	1856
50	650	1235	1783
51	625	1187	1713
52	601	1142	1648
53	579	1099	1587
54	557	1059	1528
55	537	1020	1473
56	518	984	1421
57	500	950	1372
58	483	918	1325
59	467	887	1280
60	452	857	1238
61	437	830	1198
62	423	803	1159
63	410	778	1123
64	397	754	1088
65	385	731	1055
66	373	709	1023
67	362	688	993
68	352	668	964
69	341	648	936
70	332	630	910

6, 10, 20 and 35 kV XLPE cable construction lengths are presented in the Table, they can be accommodated in standard wooden cable drums.

Construction lengths can be increased in coordination with customer using drums of greater capacity. In this way a special cable-carrying trucks; can be used in addition, one should be aware of oversized cargo transportation rules.

Comparative characteristics	XLPE cable	High pressure oil-filled cable
Continuous permissible temperature, °C	90	85
Permissible heating in emergency, °C	105	90
Ultimate permissible temperature under short-circuit current flow, °C	250	200
Density of 1-sec. short-circuit current, A/mm² — copper conductor — aluminum conductor	144 93	101 67
Relative permittivity ε at 20°C	2,5	3,3
Dielectric loss ratio, tg δ at 20°C	0,001	0,004

Main advantages of XLPE cables are the following:

- high cable transmission capability due to increased conductor permissible temperature;
- high-current thermal stability at short-circuit that is of a special importance when a cross-section has been chosen on the basis of short-circuit nominal current only;
- light-weight, smaller diameter and bending radius, which facilitates laying in both cable structures and underground along complicated routes;
- strong insulation provides enormous advantages at the laying over a sloping, hilly or rough terrain, i.e. along the routes with considerable level difference due to absence of mass dulling effect;
- absence of liquids (oils) under pressure, and consequently, no need for costly refilling equipment, that results in considerable saving in operational costs, simplification of installation equipment, cutting time and cost of cable laying, as well as installation;
- feasibility of prompt repair in case of fault;
- absence of leakages and, therefore, no risks of environmental pollution in case of damage.

Design

110-220 kV XLPE cable consists of a round copper or aluminum stranded conductor, a semiconductive layer over the conductor, a cross-linked polyethylene insulation, a semiconductive layer on the insulation, a semiconductive tape, a screen of cooper wires and a copper band, a semiconductive tape, a polyethylene sheathing, or PVC plasticate sheathing.

The conductor is covered with an extrudable screen of semiconducting material, insulation and a semiconducting screen over the insulation binded together. Insulation thickness depends upon the conductor diameter.

Metallic screen consists of copper wires and a spirally applied over them a copper band. Screen cross-section is chosen on the basis of short-circuit current flow.

In order to provide longitudinal sealing in cables indexed «F», a layer of water-swellable material is used. Contacting with water it swells thus forming a longitudinal barrier, preventing in this way moisture propagation, should damage of outside sheathing occur.

Cables indexed «FL» are provided with an alumo-polymer tape sheath welded to the polyethylene or PVC sheath apart from having longitudinal sealing. Such a design creates an effective diffusion barrier stopping ingress of water vapors; and an outside sheath of black polyethylene provides protection against mechanical damage.

Reinforced polyethylene stiffened sheath.

Cables have a sheath of black polyethylene. Cables indexed «2Y» are provided with reinforced polyethylene longitudinally stiffened sheath that is designed for preventing the sheath damage while cabling at complicated sections of cable routes.

On request of customer 110-220 kV cables can be produced with optic fiber inserted for temperature measurements along the entire length of the cable and for transmitting any signals.

110 kV XLPE cable specification

Nominal cross-section	mm^2	185	240	300	350	400	500	630	800	1000	1200	1400	1600	2000
Screen cross-section[1]	mm^2	35	35	35	35	35	35	35	35	35	50	50	50	50
Insulation thickness	mm	16,0	16,0	16,0	16,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0
Sheath thickness	mm	3,0	3,0	3,2	3,4	3,4	3,4	3,6	3,6	3,8	4,0	4,0	4,0	4,0
D outside	mm	64	66	69	70	70	73	77	81	85	91	95,8	98,1	104,6
Weight approx.[2]														
Al conductor	kg/km	3400	3700	4000	4230	4290	4830	5410	6140	7316	8422	8900	9600	11100
Cu conductor	kg/km	4560	5180	5870	6390	6760	7930	9310	11090	13699	16081	17600	19600	23600
Min. bending ra-dius	cm	95	99	104	105	105	109	116	122	128	137	144	148	157
Permissible pull-ing force														
Al conductor	kN	5,55	7,20	9,00	10,5	12,0	15,0	18,9	24,0	30,0	36,0	42,0	48,0	60,0
Cu conductor	kN	9,25	12,00	15,00	17,5	20,00	25,0	31,5	40,0	50,0	60,0	70,0	80,0	100,0
DC resistance														
Cu conductor	Ω/km	0,0991	0,0754	0,0601	0,0543	0,0470	0,0366	0,0280	0,0221	0,0176	0,0151	0,0129	0,0113	0,0090
Al conductor	Ω/km	0,1640	0,1250	0,1000	0,0890	0,0778	0,0605	0,0460	0,0367	0,0291	0,0247	0,0212	0,0186	0,0149
Inductance[3]	mH/km	0,4627	0,4439	0,4289	0,4209	0,4057	0,39	0,3781	0,363	0,351	0,339	0,334	0,330	0,317
Capacitance	μF/km	0,1364	0,1468	0,1575	0,1639	0,179	0,1936	0,209	0,2296	0,25	0,27	0,29	0,30	0,33
Continuous permis. earth current[4]														
Cu	A	500	575	650	715	755	840	935	1030	1121	1184	1248	1298	1364
Al	A	395	455	515	560	600	675	760	850	935	1009	1059	1114	1204
Continuous permis. earth current														
Cu	A	451	507	556	581	611	667	724	777	869	927	960	982	1014
Al	A	366	416	461	486	514	572	631	690	782	838	877	906	951
Continuous permis. air current[5]														
Cu	A	600	690	755	835	895	995	1115	1245	1452	1494	1598	1666	1796
Al	A	480	555	630	680	735	825	948	1060	1253	1317	1408	1483	1629
Continuous permis. air current[6]														
Cu	A	624	725	820	871	938	1065	1204	1352	1485	1533	1629	1692	1814
Al	A	494	576	656	702	758	872	999	1139	1275	1344	1446	1516	1655

1 Screen cross-section is calculated on the basis of the short-circuit current and thus can be increased. .

2 Weight is shown for cables having a polyethylene sheath and basic cross-section of the screen.

3 Calculation was performed in cabling with cables in triangle formation with immediate adjacency and earthing from both sides.

4 Currents are calculated to be buried at the depth of 1,5 m with soil specific thermal resistance of 1,20 K•m/W, and load coefficient, $K_H = 0{,}8$

5 Currents are calculated for installation in air with cables in triangle formation, clear interphase distance shall be equal to cable diameter, no solar radiation, and earthing from both sides.

6 Currents are calculated for installation in air with cables in flat formation, clear interphase distance shall be equal to cable diameter, no solar radiation, and earthing from both sides.

220 kV XLPE cable specification

Nominal cross-section	mm²	400	500	630	800	1000	1200	1400	1600	2000	2500
Screen cross-section[1]	mm²	265	265	265	265	265	265	265	265	265	265
Insulation thickness	mm	24,0	24,0	24,0	24,0	22,0	22,0	22,0	22,0	22,0	22,0
Sheath thickness	mm	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0
D outside	mm	92,3	95,3	98,9	105,4	106,1	108,9	110,6	119,7	122,7	126,2
Weight approx.[2]											
Al conductor	kg/km	9158	9739	10463	11630	11999	12834	13000	14960	16352	33000
Cu conductor		11685	12899	14445	16670	18269	20934	21800	25074	28899	33000
Min. bending radius	cm	138	142	148	158	159	163	166	179	184	190
Permissible pulling force											
Al conductor	kN	12,0	15,0	18,9	24,0	30,0	36,0	42,0	48,0	60,0	75,0
Cu conductor		20,0	25,0	31,5	40,0	50,0	60,0	70,0	80,0	100,0	125,0
DC resistance											
Cu conductor	Ω/km	0,047	0,0366	0,028	0,0221	0,0176	0,0151	0,0129	0,0113	0,009	0,0072
Al conductor		0,0778	0,0605	0,464	0,0367	0,0291	0,0247	0,0212	0,0186	0,0149	0,0119
Inductance[3]	mH/km	0,254	0,236	0,219	0,203	0,18	0,167	0,155	0,152	0,139	0,126
Capacitance	µF/km	0,133	0,143	0,154	0,174	0,119	0,220	0,220	0,240	0,230	0,270
Continuous permis. earth current[4] 	A										
Cu		638	711	785	868	938	986	1038	1072	1133	1149
Al		519	585	657	731	803	858	914	948	1018	1068
Continuous permis. earth current 	A										
Cu		620	670	725	774	812	862	892	910	940	960
Al		521	572	631	686	734	782	816	841	883	915
Continuous permis. air current[5] 	A										
Cu		800	908	1031	1160	1281	1380	1471	1547	1669	1720
Al		641	734	841	955	1071	1174	1260	1339	1464	1550
Continuous permis. air current[6] 	A										
Cu		796	884	977	1063	1136	1232	1297	1327	1393	1481
Al		658	743	836	927	1013	1101	1166	1211	1295	1395

1 Screen cross-section is calculated on the basis of the short-circuit current and thus can be increased. .

2 Weight is shown for cables having a polyethylene sheath and basic cross-section of the screen.

3 Calculation was performed in cabling with cables in triangle formation with immediate adjacency and earthing from both sides.

4 Currents are calculated to be buried at the depth of 1,5 m with soil specific thermal resistance of 1,20 K•m/W, and load coefficient, $K_H = 0{,}8$

5 Currents are calculated for installation in air with cables in triangle formation, clear interphase distance shall be equal to cable diameter, no solar radiation, and earthing from both sides.

6 Currents are calculated for installation in air with cables in flat formation, clear interphase distance shall be equal to cable diameter, no solar radiation, and earthing from both sides.

Load capacity

Load capacity of high voltage cables is calculated under the following conditions.

Laid in ground:		**Laid in air:**	
load factor	0,8	load factor	1,0
depth of cable laying	1,5 m	ambient temperature, t°	25°C
soil thermal resistance	1,2 K•m/W	conductor temperature, t°	90°C
ambient temperature, t°	15°C	screen earthing	from both sides
conductor temperature, t°	90°C		

For underground installation and with triangle arrangement, cables shall be positioned in immediate adjacency. For overhead lines and triangle arrangement of cables the clear distance between cables is recommended be equal to 25 sm. With flat arrangement of cables, recommended clear distance between cables shall be cable diameter.

Correction factor on laying depth

Laying depth, m	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,4
Correction factor	1,08	1,05	1,03	1,01	1,0	0,98	0,97	0,96	0,94

Short-circuit currents

Short-circuit current for all types of cables are calculated on the basis of the following preconditions:

Conductor temperature	
before short-circuit	90°C
after short-circuit	250°C

Screen temperature	
before short-circuit	70°C
after short-circuit	350°C

XLPE cable can be subjected to overloads with temperatures above 90°C. In this regard, emergency overloads do not considerably affect cable service life.

One-second long permissible short-circuit currents along the conductor and through the screen shall not exceed the figures presented in the Tables.

1 sec. permissible short-circuit current in the conductor												
Conductor cross-section, mm²	185	240	300	350	400	500	630	800	1000	1200	1600	2000
copper conductor	26,5	34,3	42,9	50,1	57,2	71,5	90,1	114,4	14	172,8	230	288
aluminum conductor	17,5	22,7	28,2	33,1	37,6	47	59,2	75,2	93, 1	14,3	152	190

1 sec. permissible short-circuit current the screen										
Screen cross-section, mm²	35	50	70	95	120	150	185	210	240	265
Screen 1-sec. short-circuit current, KA	7,1	10,15	14,21	19,29	24,36	30,45	37,56	42,63	48,72	53,8

In the case of short-circuit, apart from the heating, the dynamic forces originated between cable phases shall be also taken into consideration; their values can be significant. They shall be taken into account while choosing design of cable fixing means.

Cable laying conditions and testing after high voltage cable laying

During XLPE 110-220 kV cable laying the bending radius shall be at least 15xD, where D — outside cable diameter. When cables accessories installation is carried out with the use of a special template and with preheating, minimal bending radius shall also be at least 15xD.

When installing with the use of a cable sleeve or taking by the conductor, pulling force shall not exceed the following figures

F=Sx50 N/ mm^2 — for copper conductor,
F=Sx30 N/ mm^2 — for aluminum conductor

where S — conductor area of the cross-section, mm^2.

Ambient temperature during laying shall not be lower than -5°C. With preheating, cable laying can be carried out at the following temperatures:

-15°C – for cables with PVC-plasticate sheath;
-20°C – for cables with polyethylene sheath.

Following cable installation, testing of completed cable line together with all the cable accessories shall be conducted.

Having completed a cable line and prior to its commissioning, each phase of the cable and its accessories shall be tested by increased AC voltage of 128 kV during one hour with frequency of 20 to 300 Hz. As agreed between manufacturing company and customer, it is permitted to conduct testing by nominal working AC voltage of 64 kV during 24 hours at no load, instead of the test by increased AC voltage. The test by increased DC is feasible, but not recommended, and only as agreed between manufacturing company and customer.

Cable sheath shall be tested by DC of 10 kV, applied between a metallic screen and earthing for one minute.

During Estralin HVC cable laying the requirements of «Maintenance of XLPE cable laying 110-500 kV, №ТИ/01-12» should be met.

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