

North America



# HIGH & EXTRA-HIGH VOLTAGE UNDERGROUND SOLUTIONS



**SILEC**

JANUARY 2013

# ONE COMPANY - CONNECTING THE WORLD

## **POWERFUL PRESENCE · PRODUCTS · PERFORMANCE · PEOPLE**

With 14,000 associates on six continents, General Cable is a global leader in the development, design, manufacture, marketing and distribution of copper, aluminum and fiber optic wire and cable products for the energy, industrial, specialty and communications markets.

We are one of the largest wire and cable manufacturers in the world and hold increasing share in both established and growing markets.

General Cable serves its customers through a global network of manufacturing facilities with worldwide sales representation and distribution. With a portfolio of more than 100,000 products to meet thousands of diverse applications requirements, we continue to invest in research and development in order to maintain and extend our technology leadership, developing new materials, designing new products, and creating new solutions to meet tomorrow's market challenges.

In every sector and everywhere, we are strongly positioned to help our partners achieve their objectives.

We offer our customers all the strengths and value of a large company, but our people give us the agility and responsiveness of a small one. We can service you globally or locally.

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# INTRODUCTION

## A WORLDWIDE HIGH-VOLTAGE LEADER

General Cable's Silec Brand underground transmission cabling solutions have been a recognized leader in the global electric utility market for almost half a century. With unrivalled expertise and turnkey project management, General Cable provides the innovation, quality and service to transmit power reliably and cost-effectively from production to consumption areas, from one national grid to another.

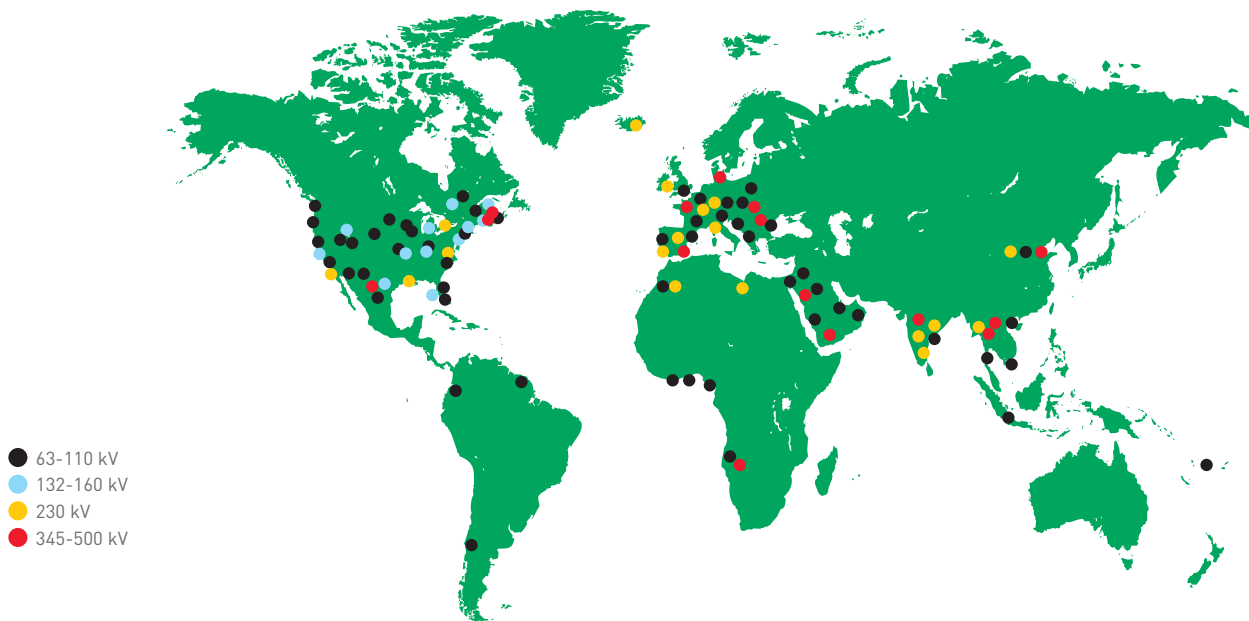
With Silec **solid-dielectric extruded high-and extra-high-voltage (HV/EHV) cable systems**, General Cable provides its global customers with superior cable system solutions that offer maximum flexibility and service life.

- » Decades of experience in underground solid-dielectric cable systems
- » Comprehensive line of high-and extra-high-voltage cable and accessories
- » Total turnkey project management from planning through installation, testing and commissioning
- » Optimized economics to keep projects on time and on budget
- » Extremely reliable, low-maintenance and long-term performance
- » Complete post-project maintenance services and responsive ongoing support



## RELY ON OUR EXPERIENCE... EXPERIENCE OUR CAPABILITIES

World leadership for HV/EHV underground transmission cable systems up to 500 kV

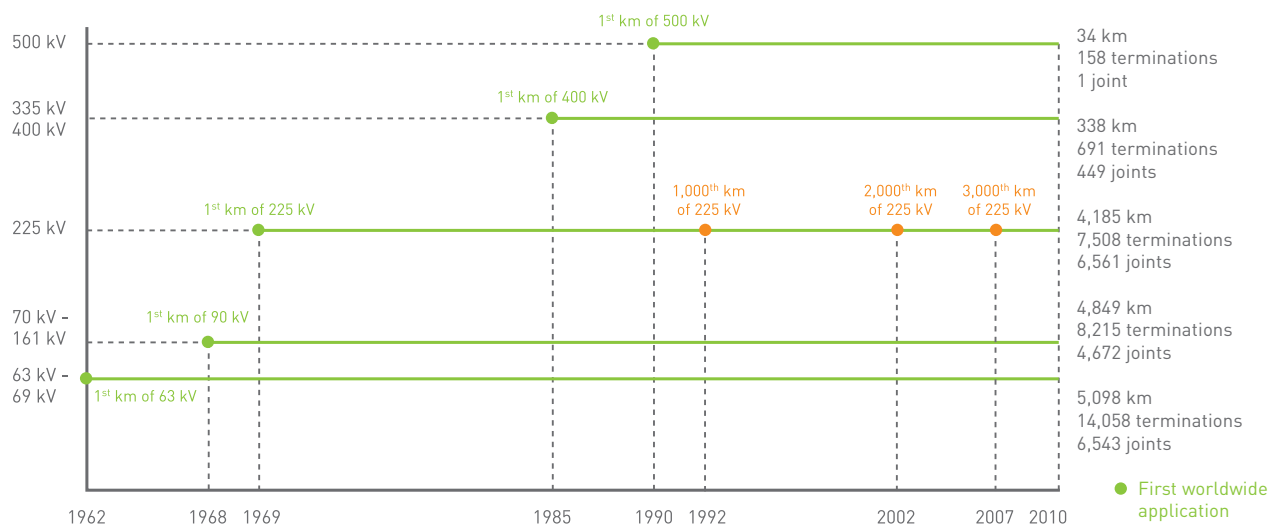


### 40 YEARS OF WORLDWIDE HIGH- & EXTRA-HIGH-VOLTAGE FIRSTS

Voltage level	63-161kV	220-230kV	330-500kV
Cable	9,947 km	4,135 km	372 km
Terminations	22,273	7,508	849
Joints	11,215	6,561	450

Ref. 2010

### VOLTAGE RANGE



Ref. 2010

The Silec Brand name has been synonymous with solid-dielectric extruded cable solutions for nearly fifty years. General Cable offers a fully integrated approach to providing a comprehensive range of quality Silec high- and extra-high-voltage cable systems. They are designed, engineered and manufactured to ensure maximum service life and best-in-class performance while maintaining cost effectiveness.

General Cable's Silec HV/EHV underground transmission cables and accessories are reliable and environmentally sound to meet the needs of current and future utility transmission systems. They exceed the requirements of our customers' technical specifications while meeting international standards like IEC 60840, IEC 60287, IEC 62067, ICEA S-108-720 and AEIC CS9.

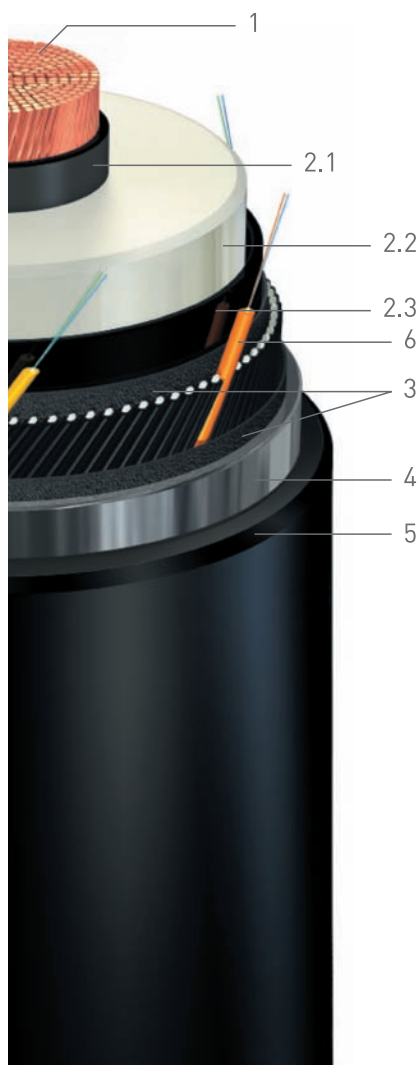
Significant in-house testing includes:

- » Qualification testing for cables up to 500 kV
- » Testing capabilities for voltage up to 700 kV
- » Partial Discharge (PD) testing to <1 pC



EHV outdoor terminations

## THE MOST COMPREHENSIVE HV/EHV SOLID-DIELECTRIC UNDERGROUND TRANSMISSION CABLE OPTIONS IN THE INDUSTRY - VOLTAGE RATINGS UP TO 500 KV



### 1 CONDUCTOR

Manufacturing up to 5,000 kcmil (2,500 mm<sup>2</sup>) conductor.

- » Copper or enameled copper or aluminium stranded wires, watertight or non-watertight
- » Compact round
- » Segmental for Milliken conductor (recommended at 2,500 kcmil or 1,200 mm<sup>2</sup> and above) to achieve high ampacities

### 2 INSULATION

Triple head extrusion process using super clean Cross-Linked Polyethylene (XLPE) provides long-term high dielectric performance.

- 2.1 Inner semi-conductive layer
- 2.2 Insulation
- 2.3 Outer semi-conductive layer

### 3 LONGITUDINAL WATER BARRIER

Swelling semi-conductive tape (under and over wire screen or optional optical fibre tubes).

### 4 METAL SCREEN/RADIAL MOISTURE BARRIER

Sheathing options for short circuit requirements and radial moisture barrier.

- » Concentric wires: copper or aluminium
- » Foil laminate: copper or aluminium
- » Welded or butt-to-butt welded
- » Lead sheath

### 5 JACKET

Jacketing options for mechanical, chemical protection.

- » High Density Polyethylene (HDPE)
- » Low Density Polyethylene (LDPE) or Linear Low Density Polyethylene (LLDPE)
- » Halogen-free fire-retardant sheathing complex
- » Fire-retardant low-smoke sheathing complex
- » Polyvinyl Chloride (PVC)
- » Conductive coating

### 6 ADDITIONAL COMPONENTS

- » Proprietary  $\mu$ Cable<sup>®</sup>, fibres (single- or multimode) within a Polyethylene (PE) tube for flexibility and improved stripability, is integrated into the high- or extra high-voltage cable for temperature monitoring via DTS system
- » General Cable can also provide standard stainless steel tube with single or multimode optical fibres
- » PD detection and other diagnostic capabilities

## HIGH- & EXTRA-HIGH-VOLTAGE CABLE ACCESSORIES

As part of the fully integrated approach and commitment to providing complete system performance, General Cable offers a wide range of Silec HV/EHV cable accessories. Vital components of an overall cable system, these accessories are designed, manufactured and precision-controlled to ensure best-in-class performance and long-term service reliability.

### A COMPLETE RANGE OF HIGH-AND EXTRA-HIGH-VOLTAGE CABLE ACCESSORIES

From 72.5 kV to 550 kV to connect cables up to 2,500mm<sup>2</sup>

Silec Brand's advanced technology in compounding and moulding of silicone, EPDM and resins translates into a complete range of high-performance accessories, from 72.5 kV to 550 kV to connect cables up to 5,000 kcmil (2,500 mm<sup>2</sup>) per IEC 60840, IEC 62067, IEEE 48, IEEE 404, ICEA S-108-720 and AEIC CS9.

Silec HV/EHV cable accessories are 100% validated through a range of calculation, modelling and testing techniques that enable General Cable to continuously adapt and optimize performance to meet the demands of our customers. General Cable offers an engineered short joint that is more space-efficient and affordable. We also provide outdoor terminations filled with ester oil, which improves on-site safety conditions and shortens installation time. With kitting options and superior logistics and distribution, General Cable ensures that our customers receive the accessories they need in days, not weeks or months.

## HIGH- & EXTRA-HIGH-VOLTAGE TURNKEY SERVICES

With more than 14,000 km of cables, 30,000 terminations and 18,000 joints installed and commissioned since 1962, General Cable's Silec underground cabling solutions are your best partner for the life of the entire cable system. From system engineering and installation to final testing and post-project services, General Cable specializes in providing turnkey service management for new cable projects or the upgrading of existing cable circuits.

With decades of experience, General Cable's HV/EHV specialists design, install and manage cable systems according to customer specifications, budgets and deadlines. We then provide the comprehensive assessment, monitoring, training and service programmes needed to extend the lifetime of the system, while at the same time reducing maintenance and optimizing operating costs.



General Cable on-site testing truck



# CABLES

# ASSUMPTIONS TO CALCULATE THE TRANSMISSION CAPACITY

In the following chapters, transmission capacities are calculated based on the following conditions:

## Load factor = 1

### Direct buried:

- » Trefoil with no space between cables
- » Laying depth: 1.5 m
- » Soil temperature: 20 °C
- » Thermal resistivity of the soil: 1.0 °C - m/W
- » No soil drying
- » No thermal proximity

### Pulled in ducts:

- » Trefoil with no space between ducts
- » Depth at the centre of the duct bank: 1.5 m
- » Soil temperature: 20 °C
- » Thermal resistivity of the soil: 1.0 °C - m/W
- » Thermal resistivity of the concrete: 1.0 °C - m/W
- » HDPE ducts
- » No soil drying
- » No thermal proximity

### Installation in free air

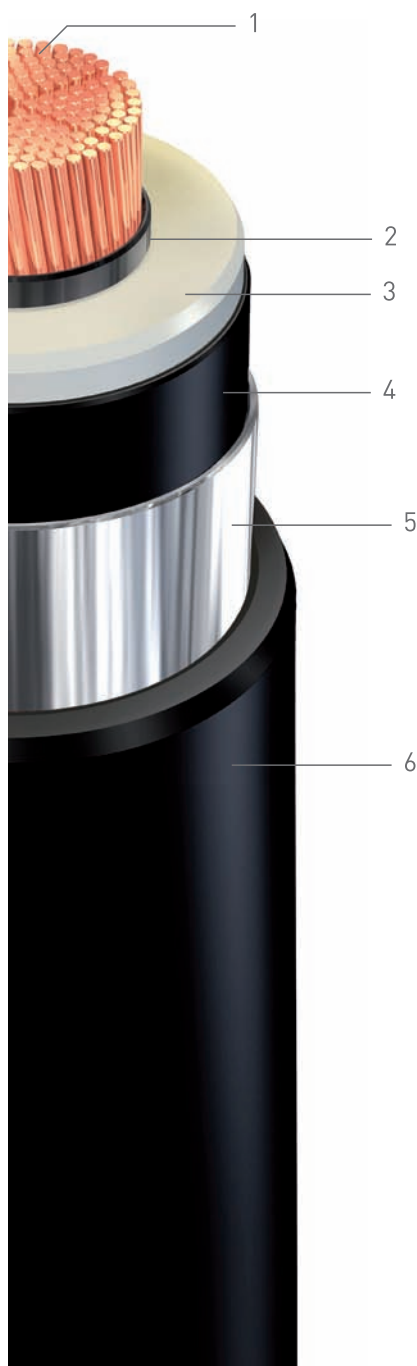
- » Trefoil with no space between cables or flat with axis-to-axis space between two conductors equal to 2 times overall diameter of cable
- » Cable exposed to solar radiation (1,000 W/m<sup>2</sup>)
- » Air temperature: 30 °C
- » No thermal proximity

Please note that the following data enable only a first assessment of the needed cross-section in relation to the power to be transmitted. This can not in any manner replace the calculations performed by General Cable's engineering department.



# WELDED ALUMINIUM SHEATH

(Specified and tested according to ICEA S-108-720, AEIC CS9 and/or IEC 60840, IEC 62067)



**Range of voltage  $U_m$ : 72.5 kV to 550 kV**

**Range of cross-section: 500 kcmil (240 mm<sup>2</sup>) to 5,000 kcmil (2,500 mm<sup>2</sup>) copper or aluminium**

## CONSTRUCTION

### 1 CONDUCTOR

Annealed copper - Class 2

Aluminium - Class 2

Concentric conductor  $\leq 2,000$  kcmil (1,000 mm<sup>2</sup>)

Milliken or optimized Milliken conductor  $\geq 2,500$  kcmil (1,200 mm<sup>2</sup>)

### 2 INNER SEMI-CONDUCTOR LAYER

Extruded semi-conducting compound

### 3 INSULATION

Cross-Linked Polyethylene (XLPE)

### 4 OUTER SEMI-CONDUCTOR LAYER

Extruded semi-conducting compound

### 5 SCREEN

Welded aluminium foil

### 6 JACKET

Jacketing options for mechanical, chemical protection.

- » High Density Polyethylene (HDPE)
- » Low Density Polyethylene (LDPE) or Linear Low Density Polyethylene (LLDPE)
- » Halogen-free fire-retardant sheathing complex
- » Fire-retardant low-smoke sheathing complex
- » Polyvinyl Chloride (PVC)
- » Conductive coating

# WELDED ALUMINIUM SHEATH

## Um = 72.5 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
500	2.31	3.84	0.022	0.028	0.075	538	541	590	612	493	417	553	532
750	2.53	4.87	0.015	0.020	0.085	652	658	733	761	581	472	672	633
1000	2.73	5.87	0.011	0.015	0.095	765	773	880	915	659	518	785	723
1250	2.90	6.95	0.009	0.012	0.105	857	870	1002	1042	718	552	874	789
1500	3.04	7.85	0.007	0.010	0.110	927	945	1100	1145	762	579	945	843
1750	3.18	8.90	0.007	0.010	0.120	988	1013	1191	1242	796	601	1007	886
2000	3.28	9.85	0.005	0.008	0.125	1043	1073	1271	1325	821	617	1053	918
2500	3.55	11.90	0.004	0.006	0.140	1267	1278	1570	1638	936	672	1236	1039
3000	3.73	13.71	0.004	0.005	0.145	1377	1394	1733	1810	985	706	1329	1099
3500	3.89	15.25	0.003	0.005	0.150	1468	1493	1875	1958	1018	730	1399	1144
4000	4.03	16.98	0.003	0.004	0.160	1552	1584	2000	2091	1039	747	1449	1168

## Um = 145 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
500	2.89	4.38	0.022	0.028	0.055	519	536	572	584	481	428	543	527
750	2.98	5.25	0.015	0.020	0.060	624	651	705	716	564	485	658	625
1000	3.14	6.23	0.011	0.015	0.065	718	759	831	838	635	534	761	710
1250	3.26	7.00	0.009	0.012	0.070	795	852	936	940	689	567	845	774
1500	3.43	8.21	0.007	0.010	0.075	853	921	1019	1018	730	594	911	826
1750	3.56	9.24	0.007	0.010	0.080	860	927	1041	1041	739	602	934	846
2000	3.65	10.17	0.005	0.008	0.080	945	1038	1161	1153	789	634	1018	904
2500	3.93	12.36	0.004	0.006	0.090	1104	1215	1392	1362	837	681	1128	1001
3000	4.10	14.17	0.004	0.005	0.095	1182	1313	1519	1477	880	710	1210	1060
3500	4.29	15.84	0.003	0.005	0.100	1234	1472	1616	1557	900	711	1263	1100
4000	4.42	17.50	0.003	0.004	0.100	1277	1549	1697	1623	916	729	1300	1135
5000	4.69	21.08	0.002	0.003	0.110	1346	1677	1841	1737	941	758	1381	1193

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

# WELDED ALUMINIUM SHEATH

## Um = 245 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
1000	3.59	6.99	0.011	0.015	0.050	707	741	813	818	628	548	753	715
1250	3.75	8.00	0.009	0.012	0.050	782	829	915	915	678	586	834	781
1500	3.88	9.01	0.007	0.010	0.055	838	895	996	993	718	614	900	834
1750	4.02	10.02	0.006	0.009	0.060	887	953	1072	1064	752	636	960	880
2000	4.14	11.03	0.005	0.008	0.060	927	1054	1134	1120	778	654	1008	919
2500	4.39	13.11	0.004	0.006	0.065	1076	1240	1355	1315	867	701	1167	1032
3000	4.57	14.92	0.004	0.005	0.065	1151	1345	1479	1430	912	723	1255	1089
3500	4.77	16.74	0.003	0.004	0.070	1201	1426	1574	1508	938	747	1319	1138
4000	4.89	18.35	0.003	0.004	0.075	1260	1506	1670	1596	974	760	1386	1176
5000	5.18	22.05	0.003	0.004	0.080	1279	1524	1718	1637	993	791	1430	1219

## Um = 362 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
1000	3.74	7.32	0.0110	0.0148	0.046	694	727	802	814	617	546	745	720
1250	3.82	8.33	0.0086	0.0120	0.049	767	813	904	912	667	584	826	788
1500	4.00	9.36	0.0072	0.0105	0.052	818	873	980	985	702	609	888	840
1750	4.00	10.43	0.0061	0.0094	0.055	865	928	1053	1055	734	623	946	886
2000	4.23	11.24	0.0053	0.0085	0.058	902	979	1117	1115	756	645	992	920
2500	4.45	13.27	0.0044	0.0059	0.061	1043	1140	1329	1305	840	697	1144	1032
3000	4.72	15.21	0.0036	0.0050	0.061	1103	1214	1439	1399	877	734	1226	1100
3500	4.96	17.00	0.0031	0.0045	0.064	1160	1279	1539	1481	909	754	1248	1146
4000	5.00	18.00	0.0027	0.0041	0.070	1284	1582	1686	1610	920	815	1296	1267
5000	5.38	22.67	0.0021	0.0035	0.076	1362	1707	1837	1737	931	841	1379	1341

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

# WELDED ALUMINIUM SHEATH

**Um = 420 kV (copper conductors) - Maximum single-phase short-circuit = 63 kA - 1 s**

Sections mm <sup>2</sup>	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
400	4.39	7.52	0.0143	0.0616	0.040	638	668	694	705	577	544	658	669
500	4.39	8.12	0.0112	0.0488	0.040	719	761	803	812	635	590	749	759
630	4.38	8.79	0.0086	0.0389	0.045	803	863	917	922	690	633	839	846
800	4.39	9.80	0.0067	0.0317	0.050	885	967	1038	1036	740	672	929	932
1000	4.63	11.61	0.0054	0.0234	0.055	1013	1121	1233	1215	782	725	1040	1036
1200	4.75	12.88	0.0046	0.0204	0.055	1078	1200	1334	1307	813	747	1103	1093
1600	5.46	18.38	0.0034	0.0159	0.060	1192	1425	1517	1469	864	789	1213	1193
2000	5.28	19.86	0.0027	0.0133	0.065	1279	1555	1672	1603	902	819	1303	1276
2500	5.58	23.55	0.0022	0.0113	0.070	1362	1674	1827	1736	936	846	1390	1353

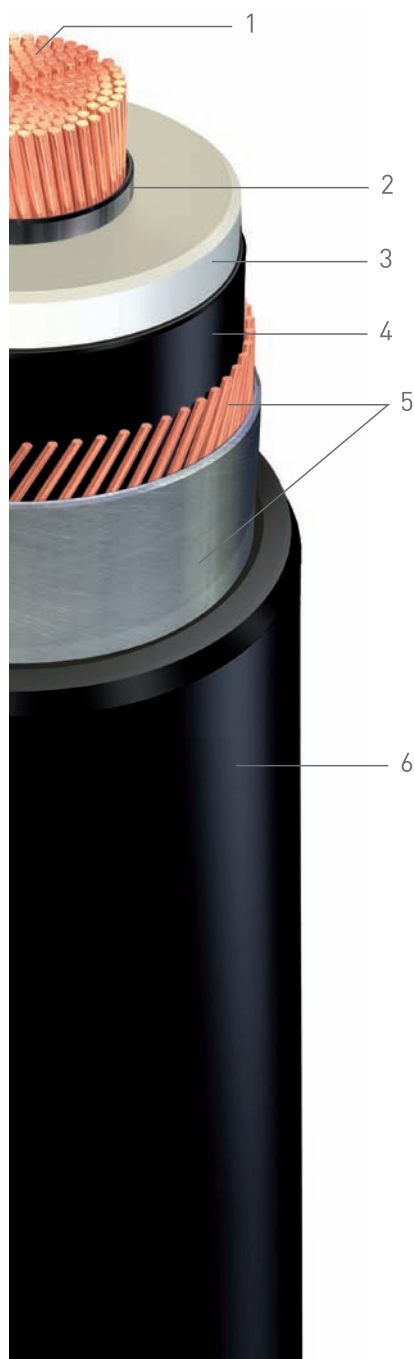
**Um = 550 kV (copper conductors) - Maximum single-phase short-circuit = 63 kA - 1 s**

Sections mm <sup>2</sup>	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
400	4.63	8.19	0.0143	0.0615	0.040	632	659	686	697	573	544	652	665
500	4.59	8.59	0.0112	0.0488	0.040	711	751	794	803	630	591	743	755
630	4.59	9.40	0.0086	0.0388	0.040	795	850	906	912	686	634	833	842
800	4.71	12.61	0.0067	0.0316	0.050	875	949	1024	1023	737	676	925	932
1000	5.04	12.88	0.0054	0.0234	0.050	1006	1146	1214	1201	784	730	1039	1037
1200	5.20	14.29	0.0046	0.0203	0.050	1066	1228	1310	1287	814	759	1104	1100
1600	5.52	18.45	0.0034	0.0158	0.055	1180	1387	1492	1449	866	799	1217	1204
2000	5.71	21.40	0.0027	0.0132	0.055	1270	1511	1649	1588	904	828	1310	1288
2500	6.01	25.16	0.0022	0.0113	0.060	1352	1623	1804	1722	938	856	1399	1368

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

# COPPER WIRES WITH LEAD SHEATH

(Specified and tested according to ICEA S-108-720, AEIC CS9 and/or IEC 60840, IEC 62067)



**Range of voltage Um: 72.5 kV to 550 kV**

**Range of cross-section: 500 kcmil (240 mm<sup>2</sup>) to 5,000 kcmil (2,500 mm<sup>2</sup>) copper or aluminium**

## CONSTRUCTION

### 1 CONDUCTOR

Annealed copper - Class 2

Aluminium - Class 2

Concentric conductor  $\leq 2,000$  kcmil (1,000 mm<sup>2</sup>)

Milliken or optimized Milliken conductor  $\geq 2,500$  kcmil (1,200 mm<sup>2</sup>)

### 2 INNER SEMI-CONDUCTOR LAYER

Extruded semi-conducting compound

### 3 INSULATION

Cross-Linked Polyethylene (XLPE)

### 4 OUTER SEMI-CONDUCTOR LAYER

Extruded semi-conducting compound

### 5 SCREEN

Copper wires and lead sheath

Optional: aluminum wires and lead sheath

### 6 JACKET

Jacketing options for mechanical, chemical protection.

- » High Density Polyethylene (HDPE)
- » Low Density Polyethylene (LDPE) or Linear Low Density Polyethylene (LLDPE)
- » Halogen-free fire-retardant sheathing complex
- » Fire-retardant low-smoke sheathing complex
- » Polyvinyl Chloride (PVC)
- » Conductive coating

# COPPER WIRES WITH LEAD SHEATH

## Um = 72,5 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
500	2.89	10.81	0.022	0.028	0.075	544	545	603	626	494	423	562	542
750	3.09	12.24	0.015	0.020	0.085	661	663	751	780	582	477	682	642
1000	3.19	13.33	0.011	0.015	0.095	772	777	896	931	659	524	795	733
1250	3.33	14.62	0.009	0.012	0.105	866	875	1020	1061	720	559	887	803
1500	3.47	16.50	0.007	0.010	0.110	935	950	1120	1167	763	586	959	856
1750	3.73	19.16	0.007	0.010	0.120	998	1017	1213	1264	801	610	1025	906
2000	3.92	21.32	0.005	0.008	0.125	1054	1078	1295	1350	835	631	1081	946
2500	4.08	23.39	0.004	0.006	0.140	1276	1283	1595	1665	948	687	1264	1065
3000	4.21	25.10	0.004	0.005	0.145	1388	1399	1761	1839	1006	728	1368	1136
3500	4.08	23.39	0.003	0.005	0.150	1481	1499	1905	1991	1049	758	1452	1190
4000	4.21	25.10	0.003	0.004	0.160	1567	1596	2033	2125	1092	788	1528	1242

## Um = 145 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
500	3.03	10.30	0.022	0.028	0.055	539	557	594	616	485	436	552	535
750	3.13	11.38	0.015	0.020	0.060	655	679	739	767	568	492	669	635
1000	3.27	12.52	0.011	0.015	0.065	764	795	877	910	642	534	776	721
1250	3.40	13.74	0.009	0.012	0.070	857	895	997	1036	699	566	862	788
1500	3.60	15.95	0.007	0.010	0.075	927	972	1093	1136	741	591	932	840
1750	3.77	17.98	0.006	0.009	0.080	990	1042	1183	1231	777	613	994	888
2000	3.84	18.40	0.005	0.008	0.080	1045	1106	1263	1314	808	629	1048	927
2500	4.11	21.16	0.004	0.006	0.090	1265	1309	1548	1612	911	677	1218	1041
3000	4.29	23.36	0.004	0.005	0.095	1375	1429	1710	1782	963	704	1313	1103
3500	4.49	25.48	0.003	0.005	0.100	1466	1529	1847	1927	1001	727	1390	1153
4000	4.61	27.36	0.003	0.004	0.100	1551	1622	1969	2054	1042	751	1464	1389
5000	4.88	31.53	0.002	0.003	0.110	1697	1787	2198	2296	1100	789	1585	1280

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher



# COPPER WIRES WITH LEAD SHEATH

## Um = 245 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
1000	3.73	12.77	0.011	0.015	0.050	758	756	855	887	633	549	764	724
1250	3.86	13.91	0.009	0.012	0.050	852	850	973	1010	688	587	849	791
1500	4.04	15.19	0.007	0.010	0.055	924	953	1068	1108	727	612	916	844
1750	4.18	16.40	0.006	0.009	0.060	987	1021	1157	1201	763	632	979	891
2000	4.30	17.61	0.005	0.008	0.010	1044	1083	1234	1291	791	651	1029	936
2500	4.57	20.03	0.004	0.006	0.065	1263	1289	1511	1571	890	699	1199	1046
3000	4.75	22.11	0.004	0.005	0.065	1377	1409	1673	1754	937	725	1291	1117
3500	4.95	24.20	0.003	0.004	0.070	1475	1511	1810	1884	975	749	1368	1160
4000	5.06	26.01	0.003	0.004	0.075	1563	1606	1937	2017	1009	769	1436	1203
5000	5.38	30.11	0.003	0.004	0.080	1722	1774	2170	2262	1070	809	1562	1284

## Um = 362 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
1000	3.92	14.42	0.0111	0.0149	0.046	748	763	837	859	653	630	801	808
1250	4.00	15.70	0.0087	0.0119	0.049	857	869	968	992	718	686	915	916
1500	4.20	17.11	0.0072	0.0107	0.052	910	1001	1097	1121	768	715	1023	1018
1750	4.33	18.34	0.0061	0.0094	0.055	970	1100	1190	1230	812	741	1119	1075
2000	4.44	19.55	0.0053	0.0085	0.058	1056	1172	1321	1342	845	777	1174	1144
2500	4.64	21.62	0.0044	0.0061	0.061	1165	1259	1431	1449	905	811	1253	1212
3000	4.92	24.31	0.0037	0.0052	0.061	1304	1345	1540	1554	987	841	1332	1284
3500	5.00	26.32	0.0032	0.0046	0.067	1385	1430	1644	1651	1032	865	1392	1329
4000	5.13	28.33	0.0027	0.0041	0.070	1435	1640	1828	1822	1085	858	1502	1421
5000	5.31	30.56	0.0021	0.0035	0.076	1546	1785	2011	1988	1125	892	1606	1505

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

### Um = 420 kV (copper conductors) - Maximum single-phase short-circuit = 63 kA - 1 s

Sections mm <sup>2</sup>	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
400	4.55	16.24	0.014	0.0616	0.040	665	678	713	735	641	605	700	715
500	4.57	16.84	0.011	0.0488	0.040	758	775	831	856	723	671	811	825
630	4.55	17.58	0.009	0.0389	0.045	857	882	958	986	807	737	927	940
800	4.57	18.58	0.007	0.0317	0.050	958	993	1095	1126	890	800	1050	1060
1000	4.79	20.46	0.005	0.0234	0.055	1125	1164	1322	1355	995	884	1229	1219
1200	4.93	22.07	0.005	0.0204	0.055	1210	1255	1440	1474	1051	927	1323	1305
1600	5.16	25.36	0.003	0.0159	0.060	1370	1484	1664	1694	1148	954	1491	1453
2000	5.46	28.71	0.003	0.0133	0.065	1499	1638	1861	1886	1216	1003	1630	1572
2500	5.77	33.00	0.002	0.0113	0.070	1620	1785	2056	2073	1272	1048	1759	1679

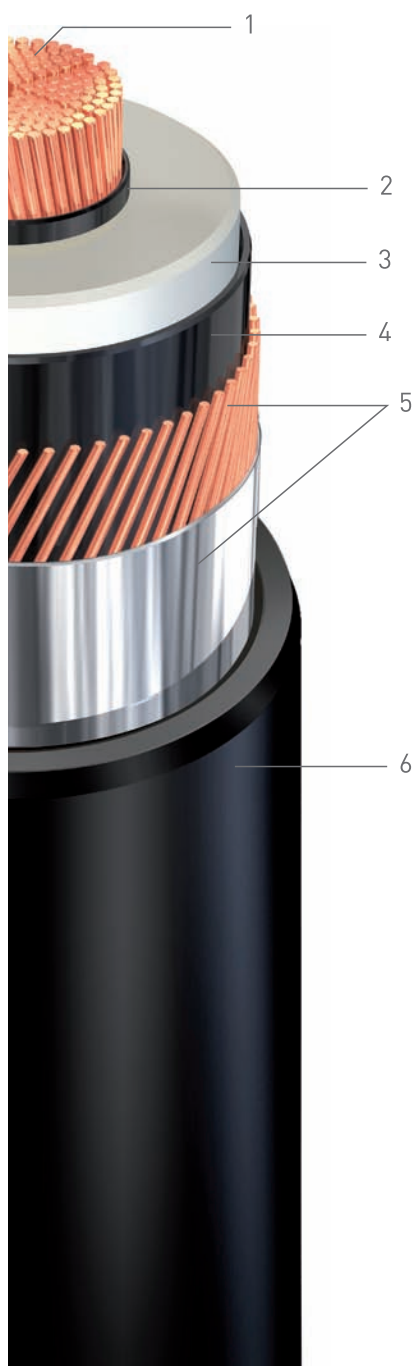
### Um = 550 kV (copper conductors) - Maximum single-phase short-circuit = 63 kA - 1 s

Sections mm <sup>2</sup>	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
400	4.79	17.18	0.0143	0.0615	0.035	659	670	704	726	635	600	691	706
500	4.75	17.58	0.0112	0.0488	0.040	751	766	821	846	716	667	801	816
630	4.77	18.38	0.0086	0.0388	0.040	849	870	945	963	799	733	916	929
800	4.89	19.79	0.0067	0.0316	0.045	949	977	1078	1108	881	797	1035	1045
1000	5.22	22.34	0.0054	0.0234	0.050	1112	1179	1292	1324	980	853	1204	1196
1200	5.38	24.15	0.0046	0.0203	0.050	1195	1271	1405	1437	1034	891	1295	1278
1600	5.63	27.50	0.0034	0.0158	0.055	1353	1452	1624	1643	1128	957	1461	1426
2000	5.91	30.86	0.0027	0.0132	0.055	1481	1601	1817	1842	1195	1007	1599	1545
2500	6.23	35.22	0.0022	0.0113	0.060	1601	1742	2010	2026	1251	1053	1728	1653

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

# COPPER WIRES WITH ALUMINIUM LAMINATED FOIL

(Specified and tested according to ICEA S-108-720, AEIC CS9 and/or IEC 60840, IEC 62067)



**Range of voltage Um: 72.5 kV to 550 kV**

**Range of cross-section: 500 kcmil (240 mm<sup>2</sup>) to 5,000 kcmil (2,500 mm<sup>2</sup>) copper or aluminium**

## CONSTRUCTION

### 1 CONDUCTOR

Annealed copper - Class 2

Aluminium - Class 2

Concentric conductor  $\leq 2,000$  kcmil (1,000 mm<sup>2</sup>)

Milliken or optimized Milliken conductor  $\geq 2,500$  kcmil (1,200 mm<sup>2</sup>)

### 2 INNER SEMI-CONDUCTIVE LAYER

Extruded semi-conducting compound

### 3 INSULATION

Cross-Linked Polyethylene (XLPE)

### 4 OUTER SEMI-CONDUCTIVE LAYER

Extruded semi-conducting compound

### 5 SCREEN

Copper wires plus metallic foil bonded to the sheath

Optional: aluminum wires

### 6 JACKET

Jacketing options for mechanical, chemical protection.

- » High Density Polyethylene (HDPE)
- » Low Density Polyethylene (LDPE) or Linear Low Density Polyethylene (LLDPE)
- » Halogen-free fire-retardant sheathing complex
- » Fire-retardant low-smoke sheathing complex
- » Polyvinyl Chloride (PVC)
- » Conductive coating

# COPPER WIRES WITH ALUMINIUM LAMINATED FOIL

## Um = 72.5 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
500	2.31	3.84	0.022	0.028	0.075	538	541	590	612	493	417	553	532
750	2.53	4.87	0.015	0.020	0.085	652	658	733	761	581	472	672	633
1000	2.73	5.87	0.011	0.015	0.095	765	773	880	915	659	518	785	723
1250	2.90	6.95	0.009	0.012	0.105	857	870	1002	1042	718	552	874	789
1500	3.04	7.85	0.007	0.010	0.110	927	945	1100	1145	762	579	945	843
1750	3.18	8.90	0.007	0.010	0.120	988	1013	1191	1242	796	601	1007	886
2000	3.28	9.85	0.005	0.008	0.125	1043	1073	1271	1325	821	617	1053	918
2500	3.55	11.90	0.004	0.006	0.140	1267	1278	1570	1638	936	672	1236	1039
3000	3.73	13.71	0.004	0.005	0.145	1377	1394	1733	1810	985	706	1329	1099
3500	3.89	15.25	0.003	0.005	0.150	1468	1493	1875	1958	1018	730	1399	1144
4000	4.03	16.98	0.003	0.004	0.160	1552	1584	2000	2091	1039	747	1449	1168

## Um = 145 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
500	2.87	5.10	0.022	0.028	0.055	534	553	584	605	482	430	543	525
750	2.97	5.95	0.015	0.020	0.060	650	674	727	754	568	483	661	625
1000	3.27	7.93	0.011	0.015	0.065	759	791	865	898	644	529	769	712
1250	3.24	7.93	0.009	0.012	0.070	851	891	983	1021	699	561	854	777
1500	3.44	8.98	0.007	0.010	0.075	921	968	1078	1120	743	586	923	829
1750	3.58	10.07	0.006	0.009	0.080	981	1038	1166	1213	778	607	985	877
2000	3.68	10.97	0.005	0.008	0.080	1037	1101	1244	1295	812	624	1040	916
2500	3.96	13.19	0.004	0.006	0.090	1256	1303	1529	1592	920	673	1214	1032
3000	4.14	15.02	0.004	0.005	0.095	1366	1423	1688	1759	976	703	1313	1101
3500	4.33	16.72	0.003	0.005	0.100	1457	1524	1824	1901	1016	726	1390	1150
4000	4.45	18.43	0.003	0.004	0.100	1538	1615	1940	2024	1040	743	1444	1181
5000	4.70	21.97	0.002	0.003	0.110	1683	1780	2165	2262	1097	779	1562	1255

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

# COPPER WIRES WITH ALUMINIUM LAMINATED FOIL

## Um = 245 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
1000	3.61	7.60	0.011	0.015	0.050	755	753	848	879	636	545	761	717
1250	3.75	8.54	0.009	0.012	0.050	846	847	963	999	690	581	844	781
1500	3.90	9.48	0.007	0.010	0.055	917	919	1057	1097	733	610	914	836
1750	4.04	10.55	0.006	0.009	0.060	980	1018	1144	1188	766	625	973	882
2000	4.16	11.50	0.005	0.008	0.060	1037	1079	1221	1268	799	643	1028	923
2500	4.41	13.58	0.004	0.006	0.065	1255	1285	1497	1557	895	693	1194	1037
3000	4.59	15.39	0.004	0.005	0.070	1369	1405	1658	1724	941	719	1285	1099
3500	4.79	17.21	0.003	0.004	0.070	1466	1507	1793	1866	975	742	1356	1147
4000	4.91	18.89	0.003	0.004	0.075	1554	1602	1918	1998	1011	762	1426	1188
5000	5.20	22.31	0.003	0.004	0.080	1709	1769	2145	2236	1082	804	1560	1275

## Um = 362 kV (copper conductors)

Sections kcmil	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
1000	3.69	8.00	0.0110	0.0150	0.046	744	741	839	871	622	541	750	711
1250	3.85	9.00	0.0086	0.0122	0.049	834	832	953	989	674	576	831	775
1500	4.01	10.00	0.0072	0.0106	0.049	903	902	1043	1083	714	604	897	828
1750	4.14	11.00	0.0061	0.0094	0.055	965	999	1129	1173	746	622	956	874
2000	4.16	11.84	0.0053	0.0086	0.058	1018	1060	1207	1256	768	636	1002	906
2500	4.42	13.83	0.0044	0.0060	0.061	1230	1303	1478	1538	858	682	1160	1018
3000	4.72	15.72	0.0036	0.0052	0.067	1345	1423	1632	1699	905	712	1252	1083
3500	4.88	15.93	0.0031	0.0046	0.067	1438	1475	1768	1841	938	732	1312	1129
4000	5.18	27.51	0.0027	0.0041	0.070	1511	1662	1889	1915	1230	1001	1651	1589
5000	5.45	31.62	0.0021	0.0035	0.076	1633	1815	2090	2108	1287	1044	1782	1698

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

**Um = 420 kV (copper conductors) - Maximum single-phase short-circuit = 63 kA - 1 s**

Sections mm <sup>2</sup>	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
400	4.43	9.73	0.0143	0.0616	0.040	658	675	708	727	620	568	687	696
500	4.45	10.27	0.0112	0.0488	0.040	747	772	823	844	693	622	790	798
630	4.43	11.07	0.0086	0.0389	0.043	842	877	947	969	768	674	899	902
800	4.47	12.01	0.0067	0.0317	0.049	938	986	1079	1102	839	721	1010	1006
1000	4.67	13.62	0.0054	0.0234	0.052	1096	1154	1298	1318	914	784	1160	1132
1200	4.81	15.03	0.0046	0.0204	0.055	1173	1241	1410	1427	955	815	1238	1200
1600	5.04	17.98	0.0034	0.0159	0.058	1317	1468	1620	1626	1026	826	1377	1318
2000	5.34	20.93	0.0027	0.0133	0.064	1430	1615	1803	1797	1075	865	1490	1414
2500	5.65	24.69	0.0022	0.0113	0.067	1532	1752	1981	1959	1113	900	1592	1498

**Um = 550 kV (copper conductors) - Maximum single-phase short-circuit = 63 kA - 1 s**

Sections mm <sup>2</sup>	Overall diameter Inches	Weight lb/ft	DC conductor resistance at 20 °C Ω/1000 ft	AC apparent conductor resistance at 90 °C Ω/1000 ft	Capacitance μF/1000 ft	CONTINUOUS CURRENT RATING, A Earthing at one point				CONTINUOUS CURRENT RATING, A Earthing in several points			
						Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)	Direct buried	Pulled in ducts (Trefoil)	In air, trefoil Exposed to solar radiation (*)	In air, flat Exposed to solar radiation (*)
400	4.67	10.33	0.0143	0.0615	0.040	652	667	699	718	614	566	679	689
500	4.63	10.80	0.0112	0.0488	0.040	740	762	813	834	687	620	782	790
630	4.65	11.61	0.0086	0.0388	0.040	834	865	934	957	760	672	888	892
800	4.77	12.82	0.0067	0.0316	0.050	929	970	1063	1085	830	722	997	995
1000	5.10	14.90	0.0054	0.0234	0.050	1082	1170	1270	1289	900	759	1140	1116
1200	5.28	16.37	0.0046	0.0203	0.050	1158	1259	1378	1394	941	788	1185	1218
1600	5.52	19.39	0.0034	0.0158	0.055	1299	1434	1584	1590	1011	836	1357	1305
2000	5.79	22.41	0.0027	0.0132	0.055	1410	1573	1763	1757	1057	874	1468	1399
2500	6.11	26.23	0.0022	0.0113	0.060	1510	1703	1939	1918	1094	909	1571	1485

(\*) Without exposure to direct solar radiation, we consider the ampacity is about 20% higher

# USER'S GUIDE

## CURRENT RATINGS - CORRECTION FACTORS

The tables in this section cover the installation conditions most commonly encountered. The following correction factors have been provided in order to calculate various laying conditions based on these five parameters:

- » Temperature of the ground
- » Temperature of the air
- » Laying depth
- » Thermal resistivity of the ground
- » Proximity of circuits

The relating factors are given in the following tables:

### GROUND TEMPERATURE

Ground Temperature (°C)	10	15	20	25	30	35	40	45
Correction Factor	1.07	1.04	1	0.96	0.93	0.88	0.84	0.8

### AIR TEMPERATURE

Air Temperature (°C)	10	20	30	40	50	60
Correction Factor	1.18	1.1	1	0.9	0.79	0.67

### LAYING DEPTH

Laying Depth (m)	1.0	1.2	1.5	2.0	2.5	3.0	4.0	5.0
Correction Factor	1.05	1.03	1	0.97	0.95	0.92	0.89	0.87

### THERMAL RESISTIVITY OF THE GROUND

Thermal Resistivity (Km/W)	0.8	1.0	1.2	1.5	2.0	2.5
Correction Factor	1.09	1	0.93	0.85	0.74	0.67

### PROXIMITY OF CIRCUIT

Axis-to-axis spacing between 2 Cable Systems (*) (mm)	Number of Cable Systems (*)					
	1	2	3	4	5	6
200	1	0.78	0.67	0.61	0.60	0.57
400	1	0.83	0.73	0.68	0.67	0.65
600	1	0.86	0.78	0.75	0.72	0.70
800	1	0.89	0.80	0.78	0.75	0.74

(\*) A cable system is a set of 3 phase conductors



## CABLE HANDLING DURING INSTALLATION

### Minimum Bending Radius

- » Minimum bending radius when pulling on rolls: 30 D
- » Minimum bending radius when pulling in pipes: 35 D
- » Minimum bending radius after installation: 20 D

D = the overall diameter of the cable

### Maximum Pulling Force

A traction force is applied at one end of the cable when pulling a cable. Most of the stress is supported by the conductor, so a pulling head has to be secured to the conductor.

Use of a pulling sleeve is restricted where the pulling force is limited to a maximum of 1,125 lbs (500 daN).

Maximum tensile load on the conductor:

- » 5 daN/mm<sup>2</sup> for aluminium conductors
- » 6 daN/mm<sup>2</sup> for copper conductors

The rated tensile strength of standard pulling heads is 4000 daN.

### Maximum Sidewall Pressure

Type of design	In ducts (lbs/ft)	On rollers (lbs)
Wires + aluminium foil	700	225
Aluminium foil alone	2,000	225
Wires + lead sheath	700	225
Lead sheath alone	2,000	225
Any type of metal screen with fiber optics	700	225

The above data should be used when performing a preliminary assessment. General Cable advises its customers to contact us for the engineering of each cable link, as each project is a specific case of study.



Cables installed in tunnel

## Electro-Dynamic Forces

When a short-circuit current is circulating in 2 conductors, it creates a force between the conductors which can be calculated with the following formula:

$$F = \frac{0.2}{a} I_{cc\ peak}^2, \text{ N/m}$$

where:

- »  $I_{cc\ peak} = 2.5 I_{cc}$  (kA)
- »  $I_{cc}$  = short-circuit current RMS (kA)
- »  $a$  = axis-to-axis spacing between conductors (m)

Transportation of large delivery lengths of cable



## APPARENT TRANSMISSION CHARACTERISTICS

### Capacitance:

$$C = \frac{\varepsilon}{18 \operatorname{Ln} \left( \frac{r_2}{r_1} \right)}, \mu\text{F/km}$$

where:

- »  $\varepsilon$  = relative permittivity of the insulation
- »  $r_1$  = radius at the surface of the conductor screen (mm)
- »  $r_2$  = radius at the surface of the insulation (mm)

### Dielectric Losses:

$$W = U_0^2 C \omega \operatorname{tg} \delta \cdot 10^{-6}, \text{W/km}$$

where:

- »  $U_0$  = is the applied voltage between the conductor and the metal screen (kV)
- »  $C$  = capacitance of the cable ( $\mu\text{F/km}$ )
- »  $\omega = 2 \pi f$  where  $f$  is the frequency (Hz)
- »  $\operatorname{tg} \delta$  = is the loss angle

### Inductance

$$L = \left[ 0.05 + 0.2 \operatorname{Ln} \left( \frac{2 a_m}{d} \right) \right] 10^{-3}, \text{H/km}$$

where:

- »  $a_m$  =  $a$  in trefoil formation where  $a$  is the axis-to-axis spacing between conductors (mm)
- »  $a_m = 1.26 a$  in flat formation where  $a$  is the axis to axis spacing between conductors (mm)
- »  $d$  = diameter of the conductor (mm)

## Electric Stress

Electric stress over the surface of the conductor screen:

$$E_1 = \frac{u_0}{r_1 \ln\left(\frac{r_2}{r_1}\right)}, \text{ kV/mm}$$

Electric stress over the surface of the insulation:

$$E_2 = \frac{u_0}{r_2 \ln\left(\frac{r_2}{r_1}\right)}, \text{ kV/mm}$$

where:

- »  $U_0$  = is the applied voltage between the conductor and the metal screen (kV)
- »  $r_1$  = radius at the surface of the conductor screen (mm)
- »  $r_2$  = radius at the surface of the insulation (mm)

Stand-by links (each fitted with one GIS termination and one outdoor termination)



# ACCESSORIES

## INTRODUCTION

General Cable offers some of the most advanced high-voltage technology in the industry, with an uncompromised commitment to continuous improvement that results in superior, cost-effective cable systems with a maximum service.

Adhering to strict manufacturing standards, Silec accessories provide maximum flexibility with tight tolerances, backed by the expertise and technology to deliver quality, customized cable solutions.

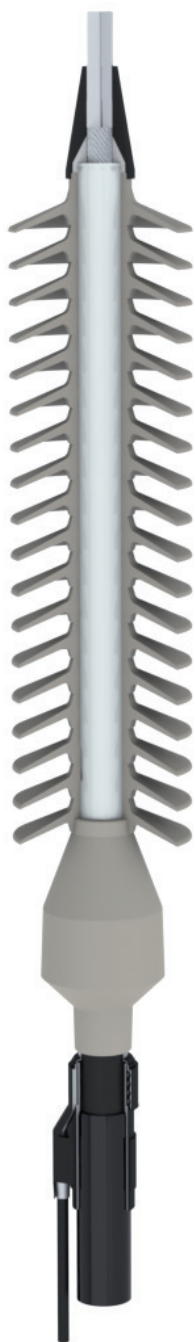
In understanding the need for maximum reliability of this vital part of the complete HV/EHV cable system, General Cable considers the following parameters when designing and recommending a cable accessory:

- » Thermo-mechanical and dynamic stress: When in service, joints and terminations can be highly stressed due to heat-cycling in service. That is why our engineering team is always carefully evaluating what types of materials and installation practices are the most suitable to ensure long-term reliability.
- » Water-tightness: It is well-known that water ingress can cause failures. The durability and ingress protection of our cable accessories are assured with sealed devices that are compliant to IEC 62067 standards. These devices are thoroughly tested in recognized international test laboratories. General Cable ensures the availability and training of highly qualified jointers to secure the reliability of the installed accessories.
- » The complete bonding system of joints and terminations is tested and approved according to the recommendations of transmission network operators.



Shielded room for testing of EHV cables (France)

# SYNTHETIC OUTDOOR TERMINATION



Maximum Rated Voltage $U_m$ (kV)	72.5	123
Basic Impulse Level (kV)	325	550
Approximate Height (mm)	1,500	2,000

These slip-on terminations are dry-types and designed for modular assembly. They are based on pre-moulded stress - the number of which is determined by the required creepage distance. These products are designed for operation under severe outdoor conditions.

- » Range of maximum rated voltage ( $U_m$ ): **72.5 to 123 kV**  
***For 145 kV and above, please contact us.***
- » Range of cable cross-section: 300 to 3,200 kcmil (150 to 1,600 mm<sup>2</sup>)
- » Pollution level: 16 mm/kV to 31 mm/kV

Various connection options for the cable conductor and the metal screen are available according to customer requests. Combined with a relevant supporting structure such as a pillar, it makes a self-supporting dry-type termination. Please contact us for more information.

# OUTDOOR TERMINATION

Maximum Rated Voltage $U_m$ (kV)	72.5	123	145	170	245	362	420	550
Basic Impulse Level (kV)	325	550	650	750	1,050	1,175	1,425	1,550
Approximate Height (mm)	1,900	2,150	2,150	6,000	6,000	4,750	4,750	6,000

These terminations are slip-on and designed for outdoor environments. They are based on pre-moulded stress-control blocks (silicone or EPDM rubber) and composite or porcelain insulators, with the overall length and the shed profile determined by the required creepage distance. These terminations are designed for operation under severe outdoor conditions, including polluted areas.

- » Range of maximum rated voltage ( $U_m$ ): **72.5 to 550 kV**
- » Range of cable cross-section: 300 to 5,000 kcmil (150 to 2,500 mm<sup>2</sup>)
- » Pollution level: 16 mm/kV to 31 mm/kV, or more on demand

Various connection options for the cable conductor and the metal screen are available according to customer requests.

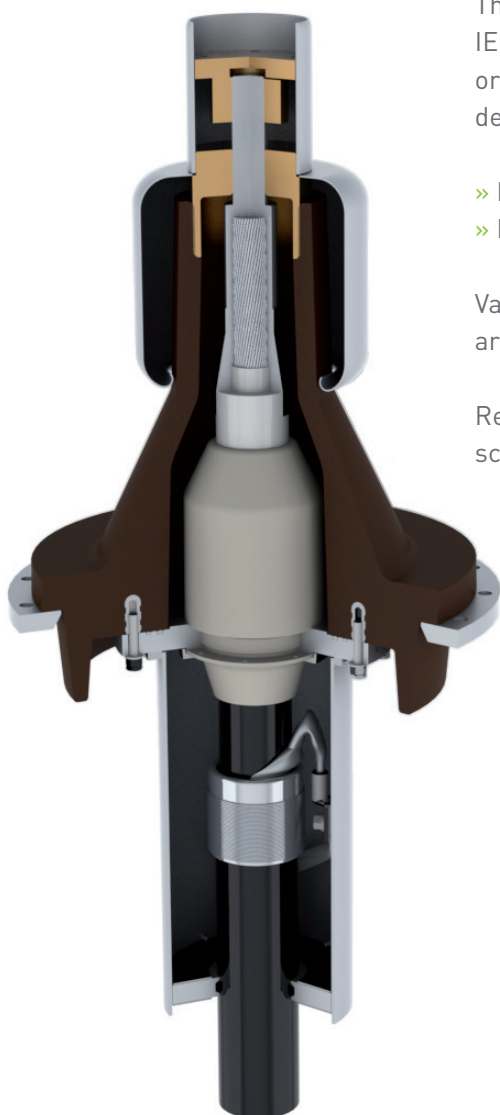
Post-insulators are used to electrically insulate the cable screen from the metallic frame.





# TERMINATION FOR METAL ENCLOSURE (GIS)

Maximum Rated Voltage $U_m$ (kV)	72.5	123	145	170	245	362	420	550
Basic Impulse Level (kV)	325	550	650	750	1,050	1,175	1,425	1,550
Overall Length (mm)	1,200	1,400	1,400	1,400	1,650	2,050	2,050	2,050



These terminations are slip-on and designed to IEC 62271-209 (formerly IEC 60859). They are based on pre-moulded stress-control blocks (silicone or EPDM rubber) and resin moulded insulators. These products are designed to be used under various service conditions.

- » Range of maximum rated voltage ( $U_m$ ): **72.5 to 550 kV**
- » Range of cable cross-section: 300 to 5,000 kcmil (150 to 2,500 mm<sup>2</sup>)

Various connection options for the cable conductor and the metal screen are available according to customer requests.

Resin insulators enable the electrical separation of the cable's metallic screen from the metal enclosure.

# OIL-IMMERSED TERMINATION FOR METAL ENCLOSURE (TRANSFORMER)

Maximum Rated Voltage $U_m$ (kV)	72.5	123	145	170	245
Basic Impulse Level (kV)	325	550	650	750	1,050
Maximum Height (mm)	1,300	1,450	1,450	1,450	1,750

These terminations are a slip-on type. They are based on pre-moulded stress-control blocks (silicone or EPDM rubber) and resin moulded insulators. These products are designed for used under various service conditions.

- » Range of maximum rated voltage ( $U_m$ ): **72.5 to 245 kV**  
*For 362 kV and above, please contact us*
- » Range of cable cross-section: 300 to 5,000 kcmil (150 to 2,500 mm<sup>2</sup>)

Various connection options for the cable conductor and the metallic screen are available according to customer requests.

Resin insulators enable the insulating of the cable's metallic screen from the metal enclosure.



# TAPED JOINTS

Maximum Rated Voltage $U_m$ (kV)	72.5	123	145
Basic Impulse Level (kV)	325	550	650
Approximate Length (mm) (*)	2,000	2,000	2,000

(\*) This length varies from one configuration to another and should be checked on a case-by-case basis.

General Cable's taped joints offer a wrapping installation technique that provides excellent flexibility and enables the connection of cables in a variety of configurations, such as reduced spaces, cables of different sizes, cables of different designs, and cables of different insulation types, to mention a few.

- » Range of maximum rated voltage ( $U_m$ ): **72.5 to 145 kV**
- » Range of cable cross-section: 300 to 5,000 kcmil (150 to 2,500 mm<sup>2</sup>)

Various connection options for the cable conductor and the metal screen are available per customer requests.



# PRE-MOULDED JOINTS

Maximum Rated Voltage $U_m$ (kV)	72.5	123	145	170	245	362	420	550
Basic Impulse Level (kV)	325	550	650	750	1,050	1,175	1,425	1,550
Approximate Length (mm)	2,000	2,000	2,300	2,400	2,600	3,000	3,000	3,200

These joints are a slip-on type. They are based on a pre-moulded stress-control block made of in-house EPDM compounds, which offers proven dielectric performance.

- » Range of maximum rated voltage ( $U_m$ ): **72.5 to 550 kV**
- » Range of cable cross-section: 300 to 5,000 kcmil (150 to 2,500 mm<sup>2</sup>)

General Cable offers pre-moulded joints with or without an earth lead, with a shield-break or whatever type of metal screen bonding is required.

Various connection options for the cable conductor and the metal screen are available per customer requests.

Three types of protection are proposed:

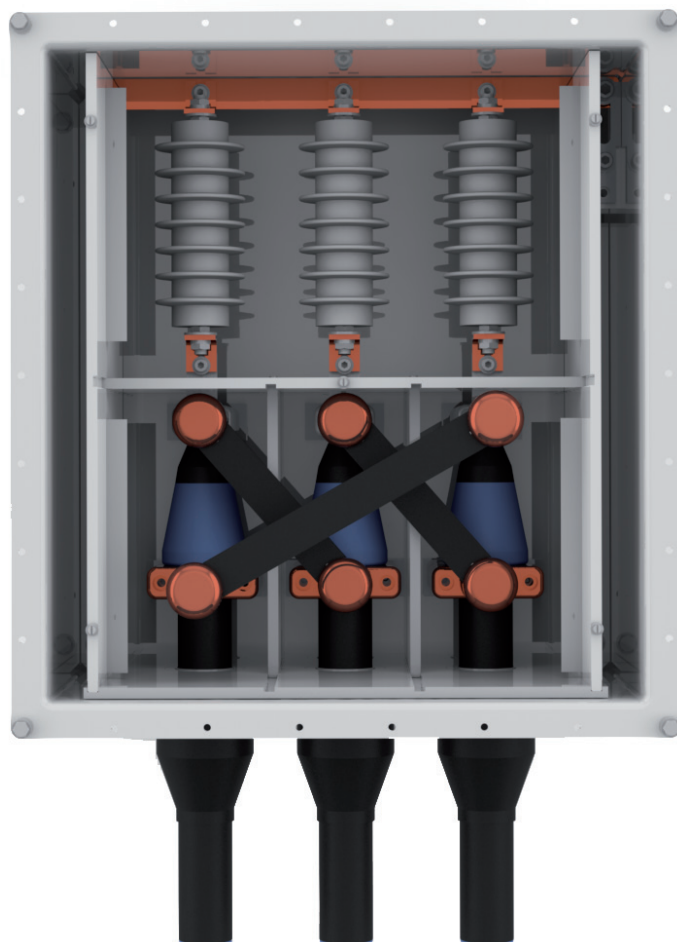
- » Aluminium foil and heat-shrink sleeves
- » Copper casing and heat-shrink sleeves
- » Copper casing, filling compound and coffin box



# LINK BOXES

Type of Link Box	Approximate Size mm x mm	Bonding
Single-Core Earthing	600 x 350	Single-Core Cable
Three-Core Earthing	600 x 600	Single-Core Cable
Cross-bonding	600 x 600 1,000 x 1,000	Coaxial cable

As required, specific link boxes can be designed to address specific project requirements.



As part of a complete cable system, link boxes are vital for the reliability of the cable system. In relation to the bonding concept, General Cable can design and supply the necessary link boxes that make it possible to:

- » Access the metallic sheath in order to test the outer protection of the system and limit transient over-voltage by the insertion of surge voltage limiters inside the boxes
- » Transpose metal screens at the joints to enable limitation of circulating currents, and protection against over-voltage by the insertion of Surge Voltage Limiters

Different types of link boxes are available for compatibility with the earthing concept at each point of the cable link:

- » Single-core earthing
- » Three-core earthing
- » Cross-bonding: 2 sizes are available, depending on the required dielectric strength

# CODIFICATION OF CABLE ACCESSORIES

To make it easy to identify what type of cable accessory is needed, you will find below the identification codes to be used for our cable accessories.

## CABLE JOINTS

### Type of accessory

PJ = pre-moulded joint  
WJ = wrapped joint

### Maximum rated voltage

72.5 for  $U_m = 72.5$  kV  
100 for  $U_m = 100$  kV  
123 for  $U_m = 123$  kV  
145 for  $U_m = 145$  kV  
170 for  $U_m = 170$  kV  
245 for  $U_m = 245$  kV  
362 for  $U_m = 362$  kV  
420 for  $U_m = 420$  kV  
550 for  $U_m = 550$  kV

### Bonding connection

SM = straight joint without earthing  
AM = straight joint with earthing  
XC = cross-bonding with coaxial lead  
X2L = cross-bonding with 2 single-core leads

### Type of metallic screen to connect

L = lead sheath  
WL = wires + lead sheath  
W = wires  
AF = aluminium foil  
WAF = wires + aluminium foil  
AS = aluminium sheath

### Radial moisture barrier of the joint

AT = aluminium tape  
CC = copper casing

### Overprotection of the joint

H = heat-shrink sleeves  
G = coffin box filled with compound  
IR = injected resin protection

### Option

OFI = embedded optical fibres internally connected  
OFE = embedded optical fibres externally connected

### Catalogue Number Construction

Example:

**PJ-123-SM-WAF-CC-H**

This is a pre-moulded straight joint without earthing, suitable for a 115 kV ( $U_m = 123$  kV) cable system. The cable has a wire screen with an aluminium foil laminate. The splice is protected within a copper casing, and there is a heat-shrink outer protection over the casing to insulate it from ground. This cable system does not have an integrated fibre.

## OUTDOOR SEALING END

### Type of accessory

OSE = outdoor sealing end

### Type of insulator

C = composite  
P = porcelain  
S = synthetic protection

### Maximum rated voltage

72.5 for  $U_m = 72.5$  kV  
100 for  $U_m = 100$  kV  
123 for  $U_m = 123$  kV  
145 for  $U_m = 145$  kV  
170 for  $U_m = 170$  kV  
245 for  $U_m = 245$  kV  
362 for  $U_m = 362$  kV  
420 for  $U_m = 420$  kV  
550 for  $U_m = 550$  kV

### Type of metallic screen to connect

L = lead sheath  
WL = wires + lead sheath  
W = wires  
AF = aluminium foil  
WAF = wires + aluminium foil  
AS = aluminium sheath

### Pollution level

P1 = 16 mm/kV  
P2 = 20 mm/kV  
P3 = 25 mm/kV  
P4 = 31 mm/kV  
P5 = more than 31 mm/kV

### Insulation fluid

O = oil  
G = gas  
D = dry

### Option

OFE = embedded optical fibres externally connected

## METAL-ENCLOSED CONNECTION

### Type of accessory

MEC = metal-enclosed termination

### Type of insulator

R = resin  
I = directly immersed

### Maximum rated voltage

72.5 for  $U_m = 72.5$  kV  
100 for  $U_m = 100$  kV  
123 for  $U_m = 123$  kV  
145 for  $U_m = 145$  kV  
170 for  $U_m = 170$  kV  
245 for  $U_m = 245$  kV  
362 for  $U_m = 362$  kV  
420 for  $U_m = 420$  kV  
550 for  $U_m = 550$  kV

### Type of metallic screen to connect

L = lead sheath  
WL = wires + lead sheath  
W = wires  
AF = aluminium foil  
WAF = wires + aluminium foil  
AS = aluminium sheath

### Type of interface

FF859 = fluid-filled dimension according to IEC 60859  
DT859 = dry-type dimension according to IEC 60859  
FF271 = fluid-filled dimension according to IEC 62271-209  
DT271 = dry-type dimension according to IEC 62271-209  
TWS = transformer  
T299 = transformer dimension according to EN 50299

### Insulation fluid

O = oil  
G = gas  
D = dry

### Option

OFE = embedded optical fibres externally connected

## MONITORING AND DIAGNOSIS

### Monitoring of Underground Cable Link

General Cable can embed optical fibres in the metal screen of the cable and supply monitoring sensors and systems that will allow the customer to optimize the operation of the underground transmission system.

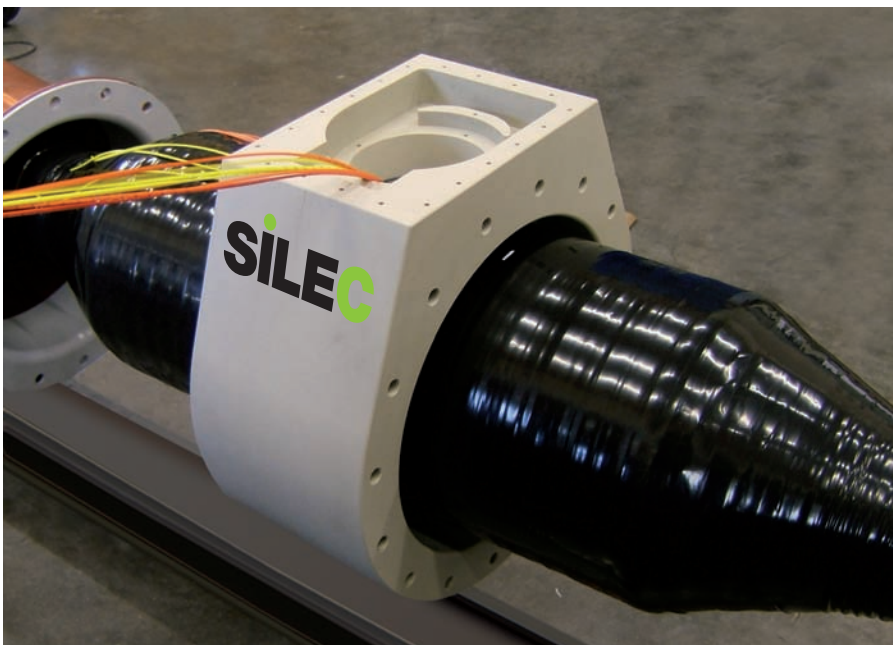
The system is designed to:

- » Measure the temperature so as to detect hot spots along the cable route
- » Calculate available transmission capacity based on the temperature of the cable and other parameters utilizing a software-based system

### On-Site PD Detection

Possible quality assessment of the cable system throughout its entire life can be offered utilizing capacitive sensors embedded in the joints of the cable system or inductive sensors set up in the link boxes.

Splicing of embedded optical fibres







# SERVICES

## TURNKEY SERVICES

Benefiting from years of experience, General Cable's HV/EHV specialists provide superior turnkey services for new cable projects or the upgrading of existing cable circuits. From system and installation engineering, project management and testing to diagnosis, post-project services and training, General Cable is your best partner to install, test and service your entire cable system.

### System Engineering & Management

Our HV/EHV specialists work to develop cable and circuit design according to your specification. Through our experienced and skilled project managers and technicians, General Cable is able to take your project from system design to installation and termination while providing the management and consulting needed to ensure that your project runs smoothly and efficiently.

- » Complete and custom cable system design
- » Project, safety and environmental management and consulting
- » On-site installation, termination and coordination

On-site testing (USA)



### On-Site Testing

General Cable performs all types of site testing needed to ensure that your system will perform and operate effectively and efficiently while meeting all required standards.

- » Cable route visual inspection
- » Serving test on oversheaths
- » Investigation of leaks (SF<sub>6</sub>, oil) and system faults and failures
- » HV-resonant tests and partial discharge measurement
- » Comprehensive test reports

### Diagnosis & Spare Parts

External events can affect your network and reduce its life expectancy. Ongoing diagnosis and assessment of your network today can help you avoid problems tomorrow. General Cable's highly advanced technical consultants and laboratories in France are well-equipped to investigate materials and components. Our experts put forth their technical knowledge to conduct comprehensive site testing, implement immediate preventive measures, and continually assess and renew your spare parts inventory to maintain ongoing operations.

- » Problem analysis and solutions
- » Prompt maintenance and replacement of circuit parts
- » Preventive technical assessments
- » Material and component testing
- » Ongoing spare parts delivery

### Training

General Cable's Silec training center provides your maintenance crews with the information they need to ensure a high level of knowledge on all Silec products, joints and terminations.

- » Customized training sessions
- » On-site training delivery
- » Ongoing refreshing of knowledge



General Cable testing & commissioning truck (Spain)

## CUSTOMER SERVICE

With more than 14,000 km of cables, 30,000 terminations and 18,000 splices installed and commissioned since 1962, General Cable is your best customer service partner. Since 2010, the Silec Services Department has met customers' expectations by speeding up implementation and improving the efficiency of our service. Our splicers, who are thoroughly trained in our dedicated on-site training center, have enriched their knowledge on several worldwide projects with a specification in High Voltage and Extra High Voltage (63 kV to 500 kV).

### Our Expedited Process

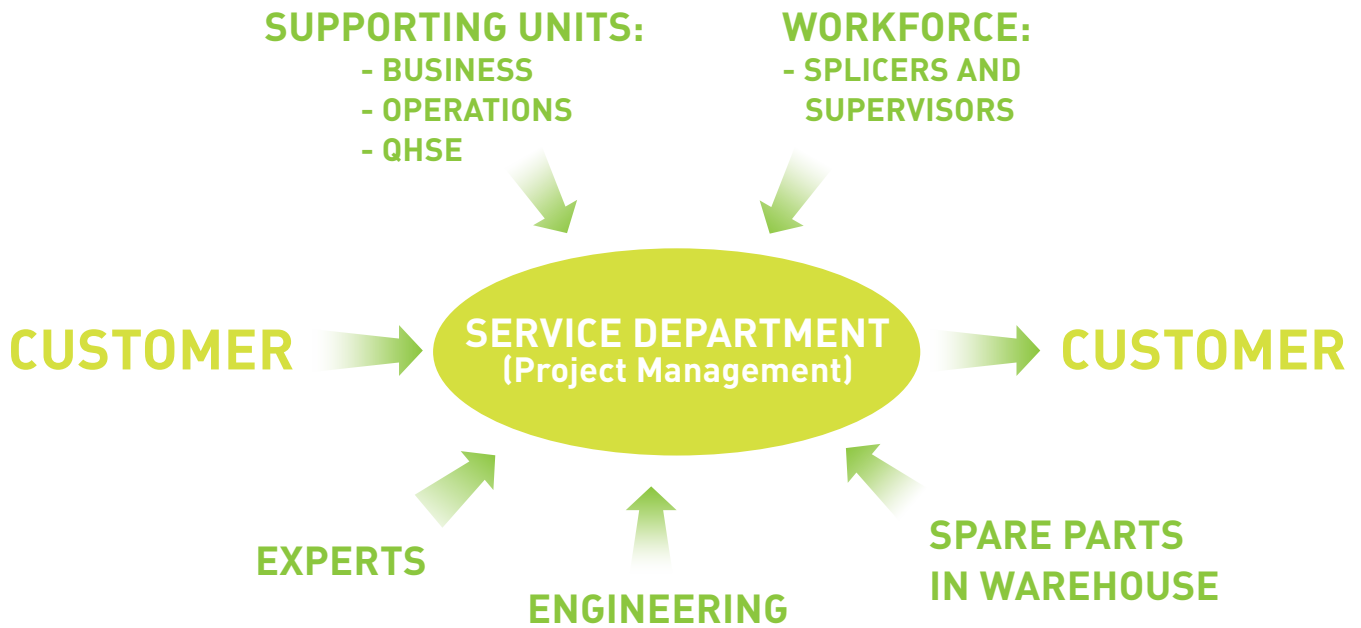
From understanding our customer needs and expectations to providing the support and installation they need, we serve you well. With our highly qualified splicers, our customers are ensured an operational network as quickly as possible. When you need us, our experts will service your needs in less than 48 hours. And with a skilled workforce spread across all five continents, General Cable is able to provide the fastest response, whatever the location. **For customer service, please send your requests to [silecna@generalcable.com](mailto:silecna@generalcable.com)**



### Skills and Resources

With the expertise, tools and workforce to deliver the best assessment, General Cable gains complete knowledge of your network to optimize customer service and value.

- » All services compliant with quality, safety, health and environmental regulations (ISO 9001 and 14001)
- » Fully-equipped portable testing units across three continents
- » Specific tools to detect and locate SF6 and oil leakages, cable damages and optical fibre faults



General Cable Projects team



# STAND-BY LINKS

General Cable has been providing customers with ready-to-use stand-by links during maintenance or repair operations in numerous applications since the 1970s, offering the continuity of service to maintain end-consumer satisfaction and avoid business losses. Some of our stand-by links have been in service for more than 60,000 hours, having undergone many connections and disconnections.

Our Silec Brand stand-by links are proposed for use during the following situations as they provide service for 60 kV to 220 kV transmission grids; constructed with outdoor sealing ends and/or metal enclosed terminations; easy to handle and set up; reusable after each disconnection; and come with tailored maintenance programs.

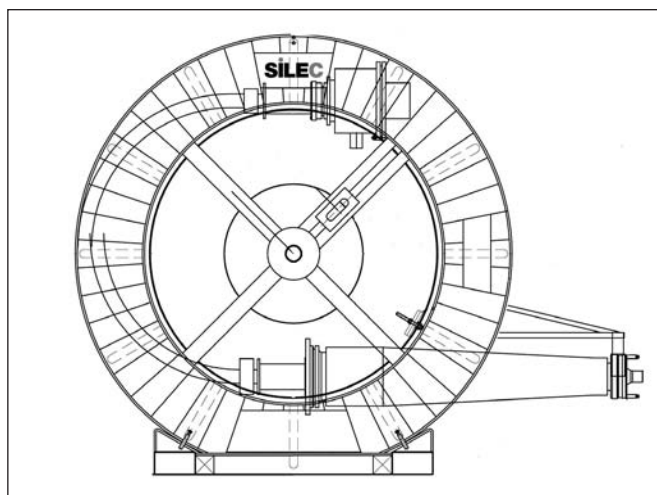
- » Refurbishment and reconstruction of tower and overhead lines
- » Restoration and expansion of high voltage substations
- » Plant substitutions in high voltage substations

For over 220 kV, please contact us.

## 1. DEDICATED DRUM

Each phase is conditioned on dedicated metallic drums fitted out to contain and protect the cable equipped with its two terminations.

Our **ready-to-use** stand-by links are typically made of 3 cable lengths fitted with outdoor sealing ends and/or metal enclosed terminations depending on your needs. Metallic gantry to support the terminations and installation components are supplied on demand.



Example of stand-by links (one outdoor and one GIS termination)



## 2. CABLE

- » A conductor generally made of aluminium wires
- » A cross-linked polyethylene insulation (XLPE)
- » An aluminium laminate screen stuck to the outer sheath
- » A thick outer sheath in High Density Polyethylene (HDPE)



The cable is designed to get a light and flexible, **easy to handle** product.

## 3. TERMINATIONS (OUTDOOR OR GIS)

To tackle to your needs, we propose different configurations: Dry Type Outdoor Termination, Composite Outdoor Termination or G.I.S. Termination.

### IN-HOUSE ASSEMBLING

The entire stand-by link system is designed, manufactured and equipped in-house to provide ready-to-use equipment.

After standard operations of manufacturing and testing, the cable is unreeled on the dedicated stand-by link drum and prepared to receive each termination.

The termination is then installed and fixed to the drum for further transportation.

Each stand-by link is finally tested in our labs before shipping.

### ON-SITE INSTALLATION

For reconstruction of tower and overhead lines, restoration and expansion in high voltage substations, or plant substitutions in high voltage substations, stand-by links are the solution for maintaining continuity of service on power networks.

General Cable can provide you with all accessories needed for the installation of a stand-by link, as well as providing the installation.

Though stand-by links are easy to use, we recommend that the first installation is done under the supervision of General Cable's trained staff as there are many advantages to the system that can be conveyed at the time of installation.



Stand-by links in service

### Steps of installation

- » Set up cable drums (3 phases)
- » Unreel cable and place terminations for further connection
- » Stand up the terminations on their support
- » Briefly interrupt power if needed. This step may have to be performed earlier depending on the configuration and safety constraints
- » Connect terminations
- » Work quietly on your network
- » Uninstall stand-by links
- » Re-condition and store until next maintenance

Our stand-by links can be set-up **rapidly** making possible the service continuity. They are easy to lay in safe conditions, leading to a **reliable connection**.

Some of our stand-by links have been in service for more than 60,000 hours combined with many connections and disconnections. After each disconnection, each stand-by link can be re-wound on its reel and is **re-usable**. Depending on the conditions of storage, installation and service of your stand-by link, General Cable implements a **tailored maintenance program**.



Typical use of stand-by link for maintenance in substations

## GLOBAL REACH

General Cable serves customers through a global network of 57 manufacturing facilities in 26 countries and sales representatives and distribution centers worldwide. The Company is solely dedicated to the production of high quality energy, industrial, specialty and communications wire and cable products. In addition to its breadth of product line and strong brand recognition, the Company offers competitive strengths in such areas as technology, manufacturing, distribution and logistics, and sales and customer service. This combination enables General Cable to better serve its customers as they expand into new geographic markets.

