HIGH CAPACITY BARE CONDUCTORS

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Revision	Data	List of modifications
02	05/10/2020	Addition of new sections of conductors and core multi-wires Renumbering of GS Type Codes
00	01/03/2018	First emission

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1 SCOPE OF THE DOCUMENT

The aim of this document is to define the technical requirements for the different technologies of high capacity concentric stranded bare conductors to be used in the high voltage overhead lines of the Enel Group Distributions Companies, listed below:

Codensa	*Colombia*
Enel Distribución Perú	*Peru*
Edesur	*Argentina*
e-distributie Banat	*Romania*
e-distributie Dobrogea	*Romania*
e-distributie Muntenia	*Romania*
e-distribuzione	*Italy*
Edistribución	*Spain*
Enel Distribución Chile	*Chile*
Enel Distribuição São Paulo	*Brazil*
Enel Distribuição Ceará	*Brazil*
Enel Distribuição Rio	*Brazil*
Enel Distribuição Goiás	*Brazil*

The document also includes the tests to be satisfied by the supplier.

2 LIST OF COMPONENTS

The list of components includes the following types of technologies of high capacity bare conductors selected for the high voltage lines of Enel Group Distribution Companies:

GS Type	Type Technology	Material Core	Material Outside core wires
Type I	Aluminum Conductor PMC Core	Polymer Matrix Composite Core (single or multi-wires)	Fully annealed Aluminum or thermal resistant aluminum Alloy wires
Type II	Aluminum Conductor MMC Core	Metal Matrix Composite Core wires	Thermal resistance Aluminum Alloy wires
Type III	ACSS/TW	Zn95Al5 Coated Steel wires	Aluminum fully annealed trapezoidal wires
Type IV	GAP	Al Clad Steel Core wires	Thermal resistance Aluminum Alloy trapezoidal & round wires

These technologies can carry electricity at higher temperature than a conventional conductor keeping sag, then it can be increased their ampacity (they are known as HTLS conductors, High Temperature Low Sag). This characteristic makes of the High Capacity Conductors a very suitable alternative for repowering a line or for spans with special requirements. The Annex 1 attaches a table with a list of cross-sections of the different technologies which are suggested to cover the complete range for the different Enel Group Distribution Companies.

It is recommended a study for each project in order to confirm the chosen conductor cross section or to propose the most appropriate one in terms of technical and economical requirements. This type of study should consider the required ampacity, the ambient conditions (temperature, sun radiation, wind speed, etc.) and the characteristics from the line (actual towers, distances, etc.).

3 REFERENCE STANDARDS

- EN 50182 Conductors for overhead lines. Round wire concentric lay stranded conductors
- EN 61232 Aluminum-clad steel wires for electrical purposes (IEC 1232)
- EN 62004 Thermal-resistant aluminum alloy wire for overhead line conductor (IEC 62004)
- EN 50540 Conductors for overhead lines. Aluminum conductors steel supported (ACSS)
- EN 62420 Concentric lay stranded overhead electrical conductors containing one or more gap(s) (IEC 62420)
- IEC 61284:1997 Overhead lines- Requirements and tests for fittings.
- EN 10244-2 Steel wire and wire products. Non-ferrous metallic coatings on steel wire. Zinc or zinc alloy coatings.
- ASTM B502: Standard Specification for Aluminum Clad Steel Core Wire for aluminum conductors
- ASTM B609: Standard specification for Aluminum 1350 wire, annealed and intermediate tempers, for electrical purposes
- ASTM B803: Standard specification for High_Strength Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Core wire for aluminum and aluminum-alloy conductors, steel reinforced.
- ASTM B856: Standard Specification for Concentric-Lay-Stranded Aluminum Conductors Steel Suported (ACSS)
- ASTM B857: Standard Specification for Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductors Steel Suported (ACSS/TW)
- ASTM B941 Standard Specification for Heat Resistant Aluminum-Zirconium Alloy Wire for Electrical Purposes
- ASTM B958 Standard draft specification for Extra-High_and Ultra-High Strength Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Core wire for aluminum and aluminum-alloy conductors, steel reinforced.
- ASTM B976: Standard Specification for Fiber Reinforced Aluminum Matrix Composite (AMC) Core Wire for Aluminum Conductors, Composite Reinforced (ACCR)
- ASTM B978: Standard Specification for Concentric-Lay-Stranded Aluminum Conductors, Composite Reinforced (ACCR)
- ASTM B987 Standard Specification for Carbon Fiber Composite Cores
- IEC 60121 Recommendation for commercial annealed aluminum electrical conductor wire
- EN 50326 Conductors for overhead lines. Characteristics of greases
- IEC 60468 Method of measurement of resistivity of metallic materials
- UNE-207009:2019 Herrajes y elementos de fijación y empalme para líneas eléctricas aéreas de alta tension.

4 SERVICE CONDITIONS

The selected conductors have all of them an appropriate behavior against pollution adverse conditions due to its technical characteristics.

In case of extreme conditions, it will be useful to analyze the site with each supplier in order to have a better estimation for the expected life of the conductor.

5 TECHNICAL CHARACTERISTICS

5.1 Conductors with composite core (PMC & MMC)

This chapter describes the aluminum conductors (annealed or thermal resistant) with composite core.

This composite core can be polymer matrix composite or metal matrix composite
The polymer matrix composite core can be formed by a single wire or multiple wires stranded and it's protected by glass fiber or aluminum tube.
Attached are the proposed technologies:

GS Type	Type Technology	Type Denomination	Material Core	Material Outside core wires
Type I	Aluminum Conductor PMC Core	PMC-I	Carbon fiber in epoxy resin matrix protected by glass fiber	Aluminum fully annealed T wires
		PMC-II	Carbon fiber in epoxy resin matrix (single wire) protected by aluminum	Aluminum fully annealed or thermal resistant aluminum zirconium alloy T or Z wires
		PMC-III	Carbon fiber in epoxy resin matrix (multiple wires) protected by aluminum	Aluminum fully annealed or thermal resistant aluminum zirconium alloy T or Z wires
Type II	Aluminum Conductor MMC Core	MMC	Aluminum oxide fibers embedded in aluminum	Thermal resistant aluminum zirconium alloy round or T wires

5.1.1 Aluminium Conductor Polymer matrix composite Core (GS Type I)

Note: Describes the materials included in the different proposed technologies (PMC)

5.1.1.1. Polymer Matrix Composite core

Core made of carbon fibers embedded in high-temperature epoxy resin matrix.

This core can be protected in different ways:

- Glass fibers to improve flexibility and toughness. It also prevents galvanic corrosion (PMC-I).
- Aluminum, which prevents thermal-oxidation and mechanic and chemical damage. Core protected by aluminum could be formed by one single wire (PMC-II) or multiple wires stranded inside the aluminum protection (PMC-III). The multiple wires core distribute the breakage risk from one to more elements, furthermore a multiple wires core is more flexible compared to a single wire core.

5.1.1.2. Annealed Aluminum Trapezoidal Wires

Conductive layers are formed by fully annealed aluminum trapezoidal wires, aluminum AL0 or 1350-O, which keeps his characteristics at high temperature and also improves conductivity and fatigue resistance.

Reference Standard for the material: EN 50540[1] and/or ASTM B609[2].

The different layers of aluminum wires are twisted around the composite core alternatively in one direction and another such that the outer layer rotates clockwise.

5.1.1.3. Thermal resistance Aluminum Alloy Trapezoidal, Z-shape or round Wires

Conductive layers are formed by Zirconium-Aluminum alloy. Zirconium confers a better mechanical behaviour at higher operating temperatures and prevents the aluminum from becoming annealed when operating at high temperatures.

Reference Standard for the material: IEC 62004 and/or ASTM B941.

The different layers of aluminum wires are twisted around the core alternatively in one direction and another such that the outer layer rotates clockwise.

[1] Chapter 5.

[2] After stranding, the trapezoidal aluminum wires shall conform to the requirements of ASTM B609 except for the shape and the diameter tolerance.

5.1.2 Aluminum Conductor Metal matrix composite Core (GS Type II)

Note: It is described the only option included in the standard (MMC)

5.1.2.1. Aluminum Matrix Composite Core Wires

The core is formed by round wires made of Aluminum oxide continuous fibres embedded in pure aluminum. It is a very high strength material with a very low thermal expansion coefficient.

5.1.2.2. Thermal resistance Aluminum Alloy Trapezoidal or round Wires

Conductive layers wires are formed by Aluminum-Zirconium alloy. Zirconium confers a better mechanical behaviour at higher operating temperatures and prevents the aluminum from becoming annealed when operating at high temperatures.

Reference Standard for the material: IEC 62004 and/or ASTM B941.

The different layers of aluminum wires are twisted around the core alternatively in one direction and another such that the outer layer rotates clockwise.

5.2 Conductor ACSS/TW (GS Type III)

Reference Standard for the conductor: EN50540 and/or ASTM B857.

5.2.1 Aluminum-Zinc Coated Steel Core Wires[3]

The core is formed by round wires made of steel coated with Aluminum-Zinc alloy (95% Zinc-5% Aluminum), with an excellent mechanical behaviour at high temperature (steel type EHST).

Reference Standard for the material: EN 50540.

[3] ACCS conductor core can be designed with different materials. It has been chosen this one because of his good behavior at high temperature.

5.2.2 Annealed Aluminum Trapezoidal Wires

Conductive layers trapezoidal wires are formed by fully annealed aluminum, type AL0 or 1350-O, which doesn't lose its properties at high temperatures and improves conductivity and fatigue resistance. Alternatively, it may be used round wires if it is more convenient.
Reference Standard for the material: EN 50540[4] and/or ASTM B609[5].

The different layers of aluminum wires are twisted around the core composite alternatively in one direction and another such that the outer layer rotates clockwise.

5.3 Conductor GAP GZTACSR (GS Type IV)

Reference Standard for the conductor: IEC 62420.

5.3.1 Aluminum cladded Steel Core Wires

The core is formed by round wires made of Aluminum steel coated, for a better behavior before corrosion (steel type 14EHSA).

Reference Standard for the material: EN50540 and/or ASTM B502.

5.3.2 Thermal resistance Aluminum alloy Trapezoidal wires

Conductive layer wires are formed by Aluminum-Zirconium alloy (aluminum alloy type AT3). Zirconium confers an excellent mechanical behaviour at higher operating temperatures and prevents the aluminum from becoming annealed when operating at high temperatures. It can be used aluminum alloy type AT1, with less thermal resistance, then the conductor is known as GTACSR and it has an inferior maximum continuous operating temperature.

Reference Standard for the material: IEC 62004 and/or ASTM B941.

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[4] Chapter 5.

[5] After stranding, the trapezoidal aluminum wires shall conform to the requirements of ASTM B609 except for the shape and the diameter tolerance.

The first layer will be formed with trapezoidal wires, creating a gap which will be filled with high thermal resistance grease.

The other layers could be made of round or trapezoidal wires and they are twisted around the core alternatively in one direction and another such that the outer layer rotates clockwise

6 CONSTRUCTION CHARACTERISTICS

High capacity bare conductors work at very high temperatures, for that reason the design of accessories (specially clamps and dead-ends) must be prepared to withstand high temperatures.
On the other hand, these conductors sometimes are made of materials not used in conventional conductors, such as composites. The accessories must be specific for every particular material.
As a consequence, this type of conductor must be treated with all their accessories as a whole system.
Regarding accessories, the reference standard is IEC-61284:1997 and paragraph 6.1.101 from UNE-207009:2019

7 TESTING

7.1 Type test

Type test shall be carried out over the conductor in order to verify its main characteristics, which depend on its design.

Each manufacturer shall make this test once to obtain the technical assessment for each conductor, and they should be repeated only when the design or manufacturing process has been modified.

7.2 Sample test

Sample test shall be carried out over final product samples to guarantee the quality of the conductors and compliance with the requirements of this standard.

7.2.1 Sample size

Sample test will carried out over in at least 10% of the reels, being tested all the wires.

If the supplier demonstrates ability to exceed the requirements, the sample can be reduced even until 10% of wires, although the size of the sample must assure the quality control of the batch.

7.3 Test description

See Annex 2.

8 SUPPLY REQUIREMENTS

8.1 Conductor packing

The conductor shall be properly protected against damage which may occur in ordinary handling and shipping.

The reels must support the conductor weight without deformations. The reel design shall respect the minimum bend radio and it will allow cranes to manipulate them.

The reel diameter will be at least 30 times the conductor diameter or 60 times the core diameter, the maximum of both values. In the case of composite core conductors, the reel diameter shall be at least 50 times the conductor or 150 times the core diameter, the maximum of both values.

For more sensitive conductors, such as fully annealed aluminum designs, it is recommended a special care: protection inside the reel, use of staves, paper between layers of conductors or similar…

Both ends of the conductor shall be secured to the spools and they will remain accessible, preventing accidental unrolling.

8.2 Conductor marking

Each reel shall be identified with a indelible and easily legible plate on the external face and in the inside, with the name of the final Enel Group distribution company. The plate shall include:

- Manufacturer name
- Conductor type
- Gross mass, net mass and tare
- Conductor length in meters
- Order number
- Reel number
- Serial number
- Manufacturing year
- Direction of rotation of the reel (with an arrow)
- Unwinding direction (if the reel is packed)

Note: The manufacturer shall use length measurement equipment with an accuracy of ± 1%

ANNEX 1 – COMPLETE LIST OF COMPONENTS WITH SUGGESTED CROSS-SECTIONS

- Data for complete conductor

GS Type Code	Standard	Type	Code Words	Size (mm^2)	Outside diameter (mm)	Mass (kg/km)	Rated strength (kN)	DC resistance (W/km)	Grease
GSCH007/001	N/A	Type I (PMC-I) ACCC	ROVINJ	217,3	17,1	576	60,4	0,1487	No
GSCH007/002			LINNET	245,9	18,29	655	60,4	0,1319	
GSCH007/003			CASABLANCA	313,3	20,5	834	85,7	0,1024	
GSCH007/004			LISBON	349,6	21,79	931	85,7	0,0916	
GSCH007/005			DOVE	408,6	23,55	1083	101,7	0,0771	
GSCH007/006			GROSBEAK	468,1	25,15	1245	112	0,0672	
GSCH007/007			WARSAW	567,8	27,72	1519	130,2	0,0553	
GSCH007/008			DRAKE	590,6	28,14	1565	153,8	0,0536	
GSCH007/009			HAMBURGO	606,7	28,63	1627	130,2	0,0514	
GSCH007/010			SAN ANTONIO	822,4	33,4	2211	162,1	0,0375	
GSCH007/015	N/A	Type I (PMC-II) ACCS	AMPERE	216,5	17,1	573	71,5	0,145	No
GSCH007/016			KIRCHHOFF	247	18,3	655	77,6	0,1263	
GSCH007/017			LENZ	311,1	20,5	824	101,4	0,1007	
GSCH007/018			FARADAY	350,2	21,8	931	103,8	0,0882	
GSCH007/019			MAXWELL	408,3	23,54	1084	124,3	0,076	
GSCH007/020			VOLTA	467,9	25,14	1243	139,2	0,0661	

GS Type Code	Standard	Type	Code Words	Size (mm^2)	Outside diameter (mm)	Mass (kg/km)	Rated strength (kN)	DC resistance (W/km)	Grease
GSCH007/021			WHEATSTONE	568,5	27,71	1518	173	0,0549	
GSCH007/022			PACINOTTI	585,5	28,12	1562	182,3	0,0535	
GSCH007/023	N/A	Type I (PMC-II) ACPR LoSag	186-AT1/28	224,7	18	591	65,5	0,1506	No
GSCH007/024			289-AT1/38	339,5	21,8	898	94,9	0,102	
GSCH007/025			377-AT1/64	465,6	25,4	1219	139,4	0,0738	
GSCH007/026			459-AT1/64	548,1	27,7	1450	152,6	0,0611	
GSCH007/027			574-AT1/64	662,7	30,4	1769	170,8	0,0494	
GSCH007/028	N/A	Type I (PMC-II) T-ACCS	THOMSON	232,8	18	604	86,5	0,1502	No
GSCH007/029			OHM	340,1	21,8	895	108,9	0,0983	
GSCH007/030			FERRARIS	460,8	25,4	1220	136	0,071	
GSCH007/031			HENRY	544,1	27,6	1452	157,7	0,0601	
GSCH007/032			MARCONI	658,2	30,4	1770	172,4	0,0485	
GSCH007/070	N/A	Type I (PMC-III) ACCM	CURIE	301,3	20,5	801	85	0,1074	No
GSCH007/071			GALVANI	341,2	21,8	910	91,4	0,0937	
GSCH007/072			FERMI	393,1	23,5	1057	99,6	0,0806	
GSCH007/073			HACK	464,4	25,1	1232	135,4	0,0701	
GSCH007/074			PLANCK	464,2	25,4	1231	134,2	0,0701	
GSCH007/075			DIRAC	546,8	27,6	1467	148,8	0,0588	
GSCH007/076			MEUCCI	583,4	28,2	1543	184	0,0572	

GS Type Code	Standard	Type	Code Words	Size (mm^2)	Outside diameter (mm)	Mass (kg/km)	Rated strength (kN)	DC resistance (W/km)	Grease
GSCH007/077			GAUSS	666,4	30,3	1776	197,3	0,0495	
GSCH007/040	N/A	Type II ACCR/TW	297-T16	175	17,2	501	53,8	0,1826	No
GSCH007/042			HAWK 477TW	281	20	801	85,148	0,1134	
GSCH007/043			OSWEGO	390	23,6	1111	115,017	0,0814	
GSCH007/044			WABASH	449	25,2	1280	139,09	0,0705	
GSCH007/045			CURLEW 1033 TW	590	28,8	1672	158,706	0,0531	
GSCH007/061	EN 50540 ASTM B857	Type III ACSS/TW	ACSS/TW-198	197,9	16,82	686	64	0,161	No
GSCH007/062			ACSS/TW-280	280,9	20,04	974	88,2	0,1134	
GSCH007/063			ACSS/TW-364	364	22,62	1215	97,3	0,0853	
GSCH007/064			ACSS/TW-455	454,9	25,24	1519	119,8	0,683	
GSCH007/065			ACSS/TW-546	546	27,53	1822	143,8	0,0569	
GSCH007/081	IEC 62420	Type IV GAP GZTACSR	GZTACSR-186	186,47	16,8	634	60,55	0,1794	Yes
GSCH007/082			GZTACSR-293	292,95	22	1000	96,76	0,1146	
GSCH007/083			GZTACSR-385	384,5	25,24	1273	113,21	0,0856	
GSCH007/084			GZTACSR-462	462,1	27,6	1521	135,2	0,0711	
GSCH007/085			GZTACSR-553	553,25	30,47	1828	164,53	0,0595	

- Data for core and for envelope wires

			Conductor Core				Conductor envelope			
GS Type Code	Type	Code Words	Material	Description	Cross section (mm^2)	Standard core	Material	Description	Cross section (mm^2)	Standard envelope
GSCH007/001	Type I (PMC-I) ACCC	ROVINJ	Polymeric Matrix Composite (PMC-I)	Hybrid carbon and glass fiber composite	28	N/A	Aluminum fully annealed AL0/1350-O	Trapezoidal wires	187,8	EN50540 ASTM B609
GSCH007/002		LINNET			28				218,1	
GSCH007/003		CASABLANCA			39,7				273,6	
GSCH007/004		LISBON			39,7				309,9	
GSCH007/005		DOVE			47,1				361,5	
GSCH007/006		GROSBEAK			51,9				416,2	
GSCH007/007		WARSAW			60,3				507,5	
GSCH007/008		DRAKE			71,3				519,7	
GSCH007/009		HAMBURGO			60,3				546,4	
GSCH007/010		SAN ANTONIO			75,1				747,3	
GSCH007/015	Type I (PMC-II) ACCS	AMPERE	Polymeric Matrix Composite (PMC-II)	Carbon fibers in polymeric matrix coated with aluminum tube	46,2	N/A		Trapezoidal or z-shaped wires	170,3	EN50540
GSCH007/016		KIRCHHOFF			48,6				198,4	
GSCH007/017		LENZ			59,6				251,5	
GSCH007/018		FARADAY			59,6				290,6	
GSCH007/019		MAXWELL			68,8				339,5	
GSCH007/020		VOLTA			74,8				393,1	
GSCH007/021		WHEATSTONE			89,5				479	
GSCH007/022		PACINOTTI			93,4				492,2	
GSCH007/023		186-AT1/28			38,6	N/A		Z-shape wires	185,9	

			Conductor Core				Conductor envelope			
GS Type Code	Type	Code Words	Material	Description	Cross section (mm^2)	Standard core	Material	Description	Cross section (mm^2)	Standard envelope
GSCH007/024	Type I (PMC-II) ACPR LoSag	289-AT1/38			50,6		Thermal resistance Al Zr Alloy AT1		289	IEC 62004 ASTM B941
GSCH007/025		377-AT1/64			88,7				376,8	
GSCH007/026		459-AT1/64			88,7				459,4	
GSCH007/027		574-AT1/64			88,7				574	
GSCH007/028	Type I (PMC-II) T-ACCS	THOMSON			65,7	N/A		Trapezoidal or Z-shaped wires	167,1	IEC 62004
GSCH007/029		OHM			71,8				268,3	
GSCH007/030		FERRARIS			79,4				381,3	
GSCH007/031		HENRY			87,8				456,3	
GSCH007/032		MARCONI			84,4				573,8	
GSCH007/070	Type I (PMC-III) ACCM	CURIE	Polymeric Matrix Composite Multiwire (PMC-III)	Carbon fiber in epoxy resin matrix (multiple wires) protected by aluminum	54,4	N/A	Thermal resistance Al Zr Alloy AT1	Trapezoidal or Z-shaped wires	246,9	IEC 62004
GSCH007/071		GALVANI			54,4				286,8	
GSCH007/072		FERMI			54,4				338,8	
GSCH007/073		HACK			77,6				386,8	
GSCH007/074		PLANCK			77,6				386,6	
GSCH007/075		DIRAC			77,6				469,2	
GSCH007/076		MEUCCI			109				474,3	
GSCH007/077		GAUSS			109				557,4	
GSCH007/040	Type II ACCR/TW	297-T16	Metal Matrix	Aluminum oxide fibers within pure Aluminum wires	25	ASTM B976	Thermal resistance Al	Round wires	150	IEC 62004 ASTM B941
GSCH007/042		HAWK 477TW			39			Trapezoidal wires	242	
GSCH007/043		OSWEGO			53				337	

			Conductor Core				Conductor envelope			
GS Type Code	**Type**	**Code Words**	**Material**	**Description**	**Cross section (mm^2)**	**Standard core**	**Material**	**Description**	**Cross section (mm^2)**	**Standard envelope**
GSCH007/044		WABASH	Composite (MMC)		62		Zr Alloy AT3		387	
GSCH007/045		CURLEW 1033 TW			67				523	
GSCH007/061	Type III ACSS/TW	ACSS/TW-198	Al-Zn coated steel wires	EHST wires (Zn95Al5 coated steel)	27,7	EN50540	Aluminum fully annealed AL0/1350-O	Trapezoidal wires	170,2	EN50540 ASTM B609
GSCH007/062		ACSS/TW-280			39,3				241,6	
GSCH007/063		ACSS/TW-364			41,8				322,2	
GSCH007/064		ACSS/TW-455			52,2				402,7	
GSCH007/065		ACSS/TW-546			62,6				483,4	
GSCH007/081	Type IV GAP GZTACSR	GZTACSR-186	Al Clad Steel wires	14EHSA steel wires	23,1	EN50540 ASTM B502	Thermal resistance Al Zr Alloy AT3	Trapezoidal & round wires	163,37	IEC62004 ASTM B941
GSCH007/082		GZTACSR-293			37,17				255,78	
GSCH007/083		GZTACSR-385			40				344,5	
GSCH007/084		GZTACSR-462			47,81				414,3	
GSCH007/085		GZTACSR-553			58,07				495,18	

ANNEX 2 – TESTING LIST

- Test for GS Type I Conductors

GSCH007 Type I		Type Test	Sample Test	Standard/paragraph
Conductor	Surface condition	X	X	EN 50540 p. 6.4.1 & 5.3
	Conductor diameter	X	X	EN 50540 p. 6.4.2 & 5.4
	Lay inalterability	X	X	EN 50540 p. 6.4.3 & 5.2.4
	Lay ratio and direction ratio	X	X	EN 50540 p. 6.4.4 & 5.2
	Number and type wire	X	X	EN 50540 p. 6.4.5
	Aluminum cross section	X	X	EN 50540 p. 6.4.6
	Mass per unit length	X	X	EN 50540 p. 6.4.7
	Resistivity (DC)	X	-	EN 50540 p. 6.4.8 & IEC 60468
	Stress-strain curve	X	-	EN 50540 p. 6.4.9 & Annex A
	Tensile test	X	-	EN 50540 p. 6.4.10
	Laying test	X	-	EN 50540 p. 6.4.11 & Annex C
Aluminum Wires	Appearance	X	X	EN 50540 / ASTM B609*
	Diameter	X	X	EN 50540 / ASTM B609*
	Strength	X	X	EN 50540 / ASTM B609*
	Elongation	X	X	EN 50540 / ASTM B609*
	Resistivity	X	X	EN 50540 / ASTM B193*
	Cross-section	X	X	EN 50540*
	Wrapping test	X	X	ISO 7802*
	Welding	X	-	IEC 50182 p. 6.5.3*
Heat resistant Aluminum-Zr Wires	Condition	X	X	EN 62004 p. 7.3.1* / ASTM B941
	Diameter	X	X	EN 62004 p. 7.3.2* / ASTM B941
	Strength	X	X	EN 62004 p. 7.3.3* / ASTM B941
	Elongation	X	X	EN 62004 p. 7.3.4* / ASTM B941
	Resistivity	X	X	EN 62004 p. 7.3.5* / ASTM B941
	Thermal resistance	X	X	EN 62004 p. 7.3.6* / ASTM B941
	Wrapping test	X	X	EN 62004 p. 7.3.7 & ISO 7802* / ASTM B941
PMC Composite core	Appearance	X	X	ASTM B987 method a
	Dimension	X	X	ASTM B987 method b
	Tensile test	X	X	ASTM B987 method c
	Glass transition temperature test	X	X	ASTM B987 method d
	Density	X	-	ASTM B987 method e
	Bending test	X	-	ASTM B987 method f
	Dye penetrant testing after bending test	X	-	ASTM B987 method g
	Tensile test after bending test	X	-	ASTM B987 method h
	Heat exposure test	X	-	ASTM B987 method i
	Heat/stress test	X	-	ASTM B987 method j
	Galvanic protection barrier layer thickness	X	-	ASTM B987 method k

- Test for GS Type II Conductors

GSCH007 Type II		Type Test	Sample Test	Standard/paragraph
Conductor	Surface condition	X	X	EN 50540 p. 6.4.1 & 5.3
	Conductor diameter	X	X	EN 50540 p. 6.4.2 & 5.4
	Lay inalterability	X	X	EN 50540 p. 6.4.3 & 5.2.4
	Lay ratio and direction ratio	X	X	EN 50540 p. 6.4.4 & 5.2
	Number and type wire	X	X	EN 50540 p. 6.4.5
	Aluminum cross section	X	X	EN 50540 p. 6.4.6
	Mass per unit length	X	X	EN 50540 p. 6.4.7
	Resistivity (DC)	X	-	EN 50540 p. 6.4.8 & IEC 60468
	Stress-strain curve	X	-	EN 50540 p. 6.4.9 & Annex A
	Tensile test	X	-	EN 50540 p. 6.4.10
	Laying test	X	-	EN 50540 p. 6.4.11 & Annex C
Heat resistant Aluminum-Zr Wires	Condition	X	X	EN 62004 p. 7.3.1 / ASTM B941
	Diameter	X	X	EN 62004 p. 7.3.2 / ASTM B941
	Strength	X	X	EN 62004 p. 7.3.3 / ASTM B941
	Elongation	X	X	EN 62004 p. 7.3.4 / ASTM B941
	Resistivity	X	X	EN 62004 p. 7.3.5 / ASTM B941
	Thermal resistance	X	X	EN 62004 p. 7.3.6 / ASTM B941
	Wrapping test	X	X	EN 62004 p. 7.3.7 & ISO 7802 / ASTM B941
MMC Composite core	Appearance	X	X	ASTM B976
	Dimension	X	X	ASTM B976
	Mass per unit length	X	X	ASTM B976
	Strength	X	X	ASTM B976

- Test for GS Type III Conductors

GSCH007 Type III		Type Test	Sample Test	Standard/paragraph
Conductor	Surface condition	X	X	EN 50540 p. 6.4.1 & 5.3
	Conductor diameter	X	X	EN 50540 p. 6.4.2 & 5.4
	Lay inalterability	X	X	EN 50540 p. 6.4.3 & 5.2.4
	Lay ratio and direction ratio	X	X	EN 50540 p. 6.4.4 & 5.2
	Number and type wire	X	X	EN 50540 p. 6.4.5
	Aluminum cross section	X	X	EN 50540 p. 6.4.6
	Mass per unit length	X	X	EN 50540 p. 6.4.7
	Resistivity (DC)	X	-	EN 50540 p. 6.4.8 & IEC 60468
	Stress-strain curve	X	-	EN 50540 p. 6.4.9 & Annex A
	Tensile test	X	-	EN 50540 p. 6.4.10
	Laying test	X	-	EN 50540 p. 6.4.11 & Annex C
Aluminum Wires	Appearance	X	X	EN 50540 / ASTM B609
	Diameter	X	X	EN 50540 / ASTM B609
	Strength	X	X	EN 50540 / ASTM B609
	Elongation	X	X	EN 50540 / ASTM B609
	Resistivity	X	X	EN 50540 / ASTM B193
	Cross-section	X	X	EN 50540
	Wrapping test	X	X	ISO 7802
	Welding	X	-	IEC 50182 p. 6.5.3
Aluminum -Zinc Coated Steel Wires	Diameter	X	X	EN 50540 p.6.5.2
	Strength	X	X	EN 50540 p.6.5.2
	Elongation or torsion	X	X	EN 50540 p.6.5.2
	Zinc mass	X	X	EN 50540 p.6.5.2
	Zinc immersion test	X	X	EN 50540 p.6.5.2
	Zinc coating adhesion test	X	X	EN 50540 p.6.5.2

- Test for GS Type IV Conductors

GSCH007 Type IV		Type Test	Sample Test	Standard/paragraph
Conductor	Surface condition	X	X	EN 50540 p. 6.4.1 & 5.3
	Conductor diameter	X	X	EN 50540 p. 6.4.2 & 5.4
	Lay inalterability	X	X	EN 50540 p. 6.4.3 & 5.2.4
	Lay ratio and direction ratio	X	X	EN 50540 p. 6.4.4 & 5.2
	Number and type wire	X	X	EN 50540 p. 6.4.5
	Aluminum cross section	X	X	EN 50540 p. 6.4.6
	Mass per unit length	X	X	EN 50540 p. 6.4.7
	Resistivity (DC)	X	-	EN 50540 p. 6.4.8 & IEC 60468
	Stress-strain curve	X	-	EN 50540 p. 6.4.9 & Annex A
	Tensile test	X	-	EN 50540 p. 6.4.10
	Laying test	X	-	EN 50540 p. 6.4.11 & Annex C
	Gaps	X	-	EN 62420 p. 6.2.3
	Creep curve	X	-	EN 62420 p. 6.2.6
Heat resistant Aluminum-Zr Wires	Condition	X	X	EN 62004 p. 7.3.1 / ASTM B941
	Diameter	X	X	EN 62004 p. 7.3.2 / ASTM B941
	Strength	X	X	EN 62004 p. 7.3.3 / ASTM B941
	Elongation	X	X	EN 62004 p. 7.3.4 / ASTM B941
	Resistivity	X	X	EN 62004 p. 7.3.5 / ASTM B941
	Thermal resistance	X	X	EN 62004 p. 7.3.6 / ASTM B941
	Wrapping test	X	X	EN 62004 p. 7.3.7 & ISO 7802 / ASTM B941
Aluminum Cladded Steel Wires	Condition	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.2 & 4.2
	Diameter	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.2 & 4.4
	Strength	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.3.1
	Elongation	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.3.2
	Torsion	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.3.3
	Aluminum thickness	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.3.4
	Resistivity	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.3.5
	Tensile test at 1% elongation	X	X	EN 50540 p.6.5.2 & EN 61232 p. 6.3.6

ANNEX 3- OPERATING TEMPERATURES AND AMPACITY RELATED

Maximum permissible temperatures

GS Type	Type Denomination	Maximum continuous operating temperature (ºC)	Maximum emergency temperature (ºC)
Type I	PMC-I	180	200
	PMC-II	150	180
	PMC-III	150	180
Type II	MMC	210	240
Type III	ACSS/TW	210	250
Type IV	GAP	210	240

Ampacity at usual and maximum operating temperature:

GS Type Code	Type	Size (mm^2)	Code Words	Ampacity @ usual operation T (75°C)	Max. Cont. T	Ampacity @ T max cont.
GSCH007/001	ACCC	217,3	ROVINJ	448	180	880
GSCH007/002	ACCC	245,9	LINNET	602	180	1014
GSCH007/003	ACCC	313,3	CASABLANCA	564	180	1120
GSCH007/004	ACCC	349,6	LISBON	611	180	1226
GSCH007/005	ACCC	408,6	DOVE	826	180	1410
GSCH007/006	ACCC	468,1	GROSBEAK	898	180	1537
GSCH007/007	ACCC	567,8	WARSAW	824	180	1673
GSCH007/008	ACCC	590,6	DRAKE	1036	180	1786
GSCH007/009	ACCC	606,7	HAMBURGO	1061	180	1834
GSCH007/010	ACCC	822,4	SAN ANTONIO	1302	180	2408
GSCH007/015	ACCS	216,5	AMPERE	454	150	773
GSCH007/016	ACCS	247	KIRCHHOFF	495	150	845
GSCH007/017	ACCS	311,1	LENZ	570	150	980
GSCH007/018	ACCS	350,2	FARADAY	618	150	1066
GSCH007/019	ACCS	408,3	MAXWELL	678	150	1175
GSCH007/020	ACCS	467,9	VOLTA	739	150	1284
GSCH007/021	ACCS	568,5	WHEATSTONE	829	150	1449
GSCH007/022	ACCS	585,5	PACINOTTI	842	150	1473
GSCH007/023	ACPR-Lo Sag	224,7	186-AT1/28	450	150	820
GSCH007/024	ACPR-Lo Sag	339,5	289-AT1/38	540	150	1040
GSCH007/025	ACPR-Lo Sag	465,6	377-AT1/64	658	150	1270
GSCH007/026	ACPR-Lo Sag	548,1	459-AT1/64	750	150	1430
GSCH007/027	ACPR-Lo Sag	662,7	574-AT1/64	875	150	1625
GSCH007/028	T-ACCS	232,8	THOMSON	452	150	771

GS Type Code	Type	Size (mm²)	Code Words	Ampacity @ usual operation T (75°C)	Max. Cont. T	Ampacity @ T max cont.
GSCH007/029	T-ACCS	340,1	OHM	586	150	1010
GSCH007/030	T-ACCS	460,8	FERRARIS	714	150	1243
GSCH007/031	T-ACCS	544,1	HENRY	791	150	1382
GSCH007/032	T-ACCS	658,2	MARCONI	898	150	1578
GSCH007/070	ACCM	54,4	CURIE	552	150	948
GSCH007/071	ACCM	54,4	GALVANI	600	150	1035
GSCH007/072	ACCM	54,4	FERMI	659	150	1141
GSCH007/073	ACCM	77,6	HACK	717	150	1247
GSCH007/074	ACCM	77,6	PLANCK	719	150	1251
GSCH007/075	ACCM	77,6	DIRAC	799	150	1397
GSCH007/076	ACCM	109	MEUCCI	814	150	1425
GSCH007/077	ACCM	109	GAUSS	890	150	1564
GSCH007/040	ACCR	175	297-T16	402	210	863
GSCH007/042	ACCR/TW	281	HAWK 477TW	530	210	1148
GSCH007/043	ACCR/TW	390	OSWEGO	650	210	1427
GSCH007/044	ACCR/TW	449	WABASH	709	210	1564
GSCH007/045	ACCR/TW	590	CURLEW 1033 TW	841	210	1885
GSCH007/061	ACSS/TW	197,9	ACSS/TW-198		210	
GSCH007/062	ACSS/TW	280,9	ACSS/TW-280		210	
GSCH007/063	ACSS/TW	364	ACSS/TW-364		210	
GSCH007/064	ACSS/TW	454,9	ACSS/TW-455		210	
GSCH007/065	ACSS/TW	546	ACSS/TW-546		210	
GSCH007/081	GAP GZTACSR	186,47	G(Z)TACSR-186	440	210	860
GSCH007/082	GAP GZTACSR	292,95	G(Z)TACSR-293	540	210	1180
GSCH007/083	GAP GZTACSR	384,5	G(Z)TACSR-385	640	210	1420
GSCH007/084	GAP GZTACSR	462,1	G(Z)TACSR-462	720	210	1610
GSCH007/085	GAP GZTACSR	553,25	G(Z)TACSR-553	800	210	1750

Conditions: 40 °C ambient temperature, wind 0,61m/s, elevation 0m, sun radiation 1033W/m², emissivity and absorption, 0,5

ANNEX 4 – COMPARATIVE TABLES

Due to similarities of the technologies included in Type I conductors (PMC), it is possible to find sections from different technologies with very similar overall characteristics. Furthermore, it could be possible to choose anyone of them to fulfil the mechanical requirements of the same project, based on availability and needed ampacity.

Equivalents sections are presented in the following table based on similar outside diameter:

	Equivalents GS Type Codes				
Outside diameter (mm)	**ACCC PMC-I**	**ACCS PMC-II**	**ACPR Lo-Sag PMC-II**	**T-ACCS PMC-II**	**ACCM PMC-III**
17,1	GSCH007/001 ROVINJ	GSCH007/015 AMPERE			
18			GSCH007/023 186-AT1/28	GSCH007/028 THOMSON	
18,29-18,3	GSCH007/002 LINNET	GSCH007/016 KIRCHHOFF			
20,5	GSCH007/003 CASABLANCA	GSCH007/017 LENZ			GSCH007/070 CURIE
21,79-21,8	GSCH007/004 LISBON	GSCH007/018 FARADAY	GSCH007/024 289-AT1/38	GSCH007/029 OHM	GSCH007/071 GALVANI
23,5	GSCH007/005 DOVE	GSCH007/019 MAXWELL			GSCH007/072 FERMI
25,1	GSCH007/006 GROSBEAK	GSCH007/020 VOLTA			GSCH007/073 HACK
25,4			GSCH007/025 377-AT1/64	GSCH007/030 FERRARIS	GSCH007/074 PLANCK
27,6-27,72	GSCH007/007 WARSAW	GSCH007/021 WHEATSTONE	GSCH007/026 459-AT1/64	GSCH007/031 HENRY	GSCH007/075 DIRAC
28,12-28,2	GSCH007/008 DRAKE	GSCH007/022 PACINOTTI			GSCH007/076 MEUCCI
30,3-30,4			GSCH007/027 574-AT1/64	GSCH007/032 MARCONI	GSCH007/077 GAUSS

COMMON LIST					
GS Type Code	**Type**	**Code Words**	**Distribution Company and Country**	**Country Code**	**TAM Description**
GSCH007/001	ACCC	ROVINJ	Enel Brazil	T310454	CABO,217,3MM,ROVINJ,ACCC, 69/138,GSCH7/1
GSCH007/002	ACCC	LINNET	Enel Brazil	T310072	CONDUTOR ALUMINIO ACCC LINNET 218,1mm², 69/138 kV, ALUMINIO 1350 COM ALMA DE FIBRA DE CARBONO,GSCH007/2
GSCH007/004	ACCC	LISBON	Enel Brazil	T310453	CABO, 349,6MM,LISBON,ACCC, 69/138, GSCH7/4
GSCH007/005	ACCC	DOVE	Enel Brazil	T310452	CABO,408,6MM,DOVE,ACCC, 69/138,GSCH7/5
GSCH007/008	ACCC	DRAKE	Enel Brazil	T310451	CABO,590,6MM,DRAKE,ACCC, 69/138,GSCH7/8
GSCH007/015	ACCS	AMPERE	Enel Brazil	T310450	CABO,216,5MM,AMPERE,ACCS, 69/138,GSCH7/15
GSCH007/016	ACCS	KIRCHHOFF	Enel Brazil	T310449	CABO,247MM,KIRCHHOF,ACCS, 69/138,GSCH7/16
GSCH007/018	ACCS	FARADAY	Enel Brazil	T310448	CABO,350MM,FARADAY,ACCS, 69/138,GSCH7/18
GSCH007/019	ACCS	MAXWELL	Enel Brazil	T310447	CABO,408MM,MAXWELL,ACCS, 69/138,GSCH7/19
GSCH007/022	ACCS	PACINOTTI	Enel Brazil	T310446	CABO,585MM,PACINOTT,ACCS, 69/138,GSCH7/22
GSCH007/023	ACPR LoSag	186-AT1/28	Enel Brazil	T310445	CABO,224,7MM,AT1/28,ACPR, 69/138,GSCH7/23
GSCH007/024	ACPR LoSag	289-AT1/38	Enel Brazil	T310444	CABO,339,5MM,AT1/38,ACPR, 69/138,GSCH7/24
GSCH007/026	ACPR LoSag	459-AT1/64	Enel Brazil	T310443	CABO,548,1MM,AT1/64,ACPR, 69/138, GSCH7/26
GSCH007/028	T-ACCS	THOMSON	Enel Brazil	T310442	CABO,232MM,THOMSON,TACCS ,69/138,GSCH7/28
GSCH007/029	T-ACCS	OHM	Enel Brazil	T310441	CABO,340,1MM,OHM,T-ACCS, 69/138,GSCH7/29
GSCH007/031	T-ACCS	HENRY	Enel Brazil	T310440	CABO,544MM,HENRY,T-ACCS, 69/138,GSCH7/31
GSCH007/040	ACCR/TW	297-T16	Enel Brazil	T310439	CABO,175MM,291T16,ACCRTW,69/ 138,GSCH7/40
GSCH007/042	ACCR/TW	HAWK 477 TW	Enel Brazil	T310173	CABO,281MM,HAWK,ACCR/TW,69/ 138,GSCH7/42
GSCH007/043	ACCR/TW	OSWEGO	Enel Brazil	T310172	CABO,390MM,OSWEG,ACCR/TW,6 9/138,GSCH7/43
GSCH007/045	ACCR/TW	CURLEW 1033 TW	Enel Brazil	T310171	CABO,590MM,CURLE,ACCR/TW,69/ 138,GSCH7/45
GSCH007/061	ACSS/TW	ACSS/TW-198	Enel Brazil	T310170	CABO,197,9MM,ACCR/TW198,69/13 8,GSCH7/61
GSCH007/062	ACSS/TW	ACSS/TW-280	Enel Brazil	T310169	CABO,280,9MM,ACCR/TW,69/138, GSCH7/62
GSCH007/063	ACSS/TW	ACSS/TW-364	Enel Brazil	T310168	CABO,364MM,ACCR/TW,69/138, GSCH7/63
GSCH007/065	ACSS/TW	ACSS/TW-546	Enel Brazil	T310167	CABO,546MM,ACCR/TW,69/138, GSCH7/65
GSCH007/081	GAP GZTACSR	GZTACSR-186	Enel Brazil	T310166	CABO,186,47MM,GZTACSR,69/138, GSCH7/81
GSCH007/082	GAP GZTACSR	GZTACSR-293	Enel Brazil	T310165	CABO,292,95MM,GZTACSR,69/138, GSCH7/82

COMMON LIST					
GS Type Code	**Type**	**Code Words**	**Distribution Company and Country**	**Country Code**	**TAM Description**
GSCH007/084	GAP GZTACSR	GZTACSR-462	Enel Brazil	T310164	CABO,462,1MM,GZTACSR,69/138, GSCH7/84
GSCH007/004	ACCC	LISBON	Edistribución España	310008	CONDUCTOR ALTA CAPACIDAD ACCC LISBON SEGUN NORMA GSCH007 (GSCH007/004)
GSCH007/040	ACCR	297-T16	Edesur Argentina	0101-0493	Conductor de alta capacidad (ACCR) - 175 mm2
GSCH007/042	ACCR/TW	HAWK 477 TW	Edesur Argentina	0101-0494	Conductor de alta capacidad (ACCR) - 281 mm2
GSCH007/044	ACCR/TW	WABASH	Edesur Argentina	0101-0495	Conductor de alta capacidad (ACCR) - 449 mm2
GSCH007/004	ACCC	LISBON	Codensa Colombia	310003	Conductor de alta capacidad ACCC 349.6 mm2 (Lisbon)
GSCH007/007	ACCC	WARSAW	Codensa Colombia	310004	Conductor de alta capacidad ACCC 567.8 mm2 (warsaw)
GSCH007/020	ACCS	VOLTA	Codensa Colombia	310002	Conductor de alta capacidad ACCS 467.9 mm2 (Volta)
GSCH007/002	ACCC	LINNET	Enel Chile	310008	CONDUCTOR ACCC LINNET 245,9 MM2
GSCH007/006	ACCC	GROSBEAK	Enel Chile	310005	CONDUCTOR ACCC GROSBEAK 481,1 MM2
GSCH007/009	ACCC	HAMBURGO	Enel Chile	310006	CONDUCTOR ACCC HAMBURGO 606,7 MM2
GSCH007/010	ACCC	SAN ANTONIO	Enel Chile	310007	CONDUCTOR ACCC SAN ANTONIO 822,4 MM2