MICROGRID FOR THE ELECTRIFICATION OF THE VILLAGE OF VILLACARRIEDO (SPAIN)

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In this project the design of an isolated microgrid will be developed to electrically supply the village of Villacarriedo, Cantabria, Spain. Which consists of 130 homes and a milking parlour. It is located at a height of 211 meters above sea level.

First of all, we will design a low voltage overhead line to give electrical supply for the whole village, which will be fed in turn by a middle voltage line. Finally, we will determine the energy sources that will make up the microgrid.

1. LOW VOLTAGE OVERHEAD LINE

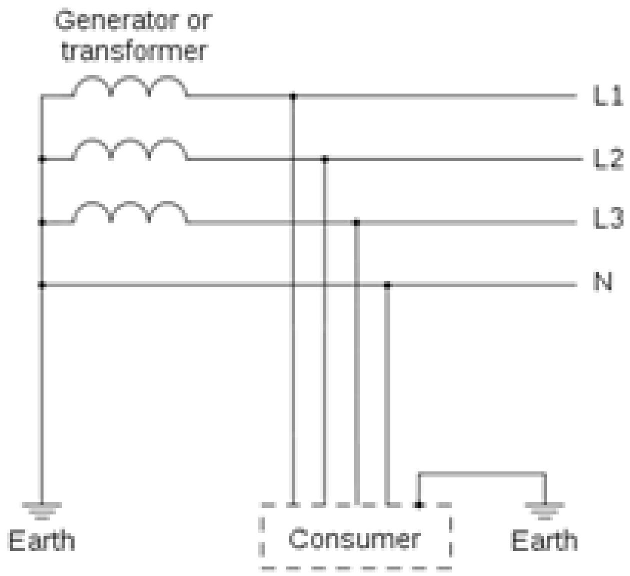
1.1 INTRODUCTION

1.1.1 Characteristics

Looking for information about low voltage lines in Spanish villages, I have seen that the most common type are low voltage overhead lines with braided conductors.

Design criteria for low voltage braided overhead lines, according to [Low Voltage Electrotechnical Regulation]:

- The value of the assigned rated voltage of the low voltage overhead line will be 400 V.
- The distribution networks in low voltage will be designed bearing in mind that, with the anticipation of current or future loads of the network, no supply must reach a voltage lower than 93% of the nominal voltage of the network. As a calculation criterion to determine the section, a maximum voltage drop of 5% will be considered.
- The design of the network will be made taking into account the maximum load to be transported, the maximum admissible current in the conductor and the electrical moment of the line.
- Conductors of main lines will be of uniform cross section.
- Conductors of derivations will also be of uniform cross section.
- The lines will be protected against overloads and short circuits.
- The frequency is 50 Hz.
- In mostly residential areas the power factor is 0.9.
- The distribution scheme for receiving installations fed directly from a low voltage distribution network is the TT scheme. [Section 1.2, ITC-BT-08]



TT scheme

The distribution schemes are established according to the ground connections of the distribution network on the one hand, and exposed conductive parts of the receiving installation, on the other hand.

The denomination is carried out with a code of letters with the following meaning:

- First letter, T, there is one directly earthed point. It is usually the neutral point of the distribution network.
- Second letter, T, exposed conductive parts are connected directly to earth.

1.1.2 Cables

The cables to be used in this type of low voltage lines shall be, RZ type, nominal voltage 0.6 / 1 kV, formed by braided conductors of Aluminium with cross-linked polyethylene insulation (XLPE) and neutral in aluminium, magnesium and silicon alloy (Almelec) [UNE 21030:1996]

The reactance X of the conductors varies with the diameter and the separation between conductors, but in the case at hand it is sensibly constant to be together in bundle. Therefore, the value X=0.1 Ω / km is adopted, which can be entered in the calculations without appreciable error.

Characteristics of cables:

Type	RZ-0,6/1kV 2x16 Al	RZ-0,6/1kV 3x25 Al + 54,6 alm (T-25)	RZ-0,6/1kV 3x50 Al + 54,6 alm (T-50)	RZ-0,6/1kV 3x95 Al + 54,6 alm (T-95)	RZ-0,6/1kV 3x150 Al +80 alm (T-150)
Cross section Al (mm2)	16	25	50	95	150
Cross section Almelec (mm2)	-	54,6	54,6	54,6	80
Number of Aluminum Wires	7	7	19	19	37
Almelec formation (nºxϕmm)	-	7x3,15	7x3,15	7x3,15	19x2,31
Isolation	XLPE	XLPE	XLPE	XLPE	XLPE
Bundle diameter (mm)	15,8	23,05	30,25	40,5	49,375
Bundle mass (kg/km)	146	560	840	1346	1861
Almelec breaking load (daN)	-	1660	1660	1660	2000
Almelec elasticity module (daN/mm2)	6000	6200	6200	6200	6200
Almelec dilatation coefficient	-	$23x10^{-6}$	$23x10^{-6}$	$23x10^{-6}$	$23x10^{-6}$
Maximum admissible current 40ºC	73	100	150	230	305
Maximum tension (daN)	100	500	500	500	500

Next we have a table with the resistance for each phase conductor or neutral (Ω/km) (20ºC) [Table 3, UNE 21030-1]

Type	Section (mm2)	Ohmic resistance 20ºC (Ω/km)
Phase	16	1,91
	25	1,2
	50	0,641
	95	0,32
	150	0,206
Neutral	54,6	0,63
	80	0,43

1.1.3 Supports

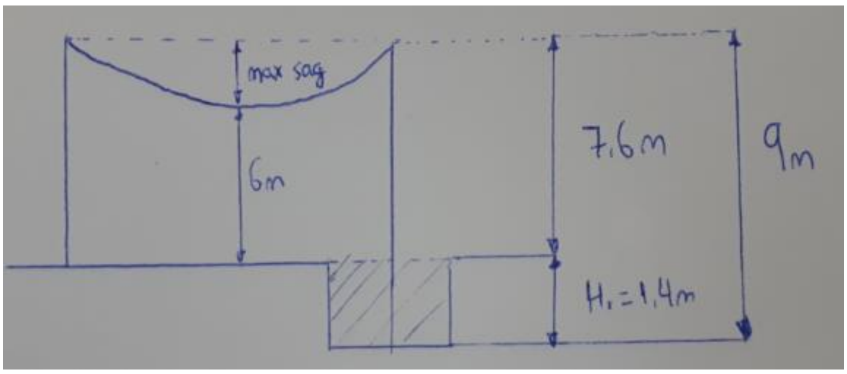
For the laying of the conductors, vibrated concrete supports of 9 meters high will be used according to the [UNE 207016: 2007] standard.

For this height the necessary foundation has the following characteristics.

$$H_1 = \frac{H}{10} + 0.5$$

Taking into account that our H = 9 meters, the height of the support that must be under ground is H1 = 1.4 meters.

The minimum height of the lowest conductor with respect to roads, in the most unfavourable arrow conditions, will be 6 meters.



So, the part of the support outside the earth has a height of 7.6 meters. Bearing in mind that the minimum safety distance from the ground to the lowest point of the cable is 6 meters, the maximum sag is 1.6m. Then we calculate the maximum span that we can use between supports.

1.1.4 Zone by altitude

In [Section 2.1 of ITC-BT 06 of the RLBT], three different zones are determined for the electric lines according to the altitude at which they are located:

- Zone A, located less than 500 meters above sea level.
- Zone B, located at an altitude between 500 and 1000 meters above sea level.
- Zone C, located at more than 1000 meters above sea level.

For the calculation of the span, we take into account that our village is in zone A (0-500m). For the calculation hypothesis of this zone the maximum sag condition occurs for a temperature of 50^0 C.

Analysing the laying tables for the different sections of conductors we can conclude that the maximum span is 45m, according to the maximum sag (1.6m) [annex C MT 2.41.20]

Since for the cable T-150 the maximum sag is just 1.6 m for 45 meters.

1.1.5 Transformers

As we will see later, we will use 400 kA transformers encapsulated in resin whose characteriscs are: [Legrand catalogue]

Sn (kVA)	Serie	Nº ref.	Primary voltage (Kv)	Secondary Voltage (V)
400	AoBk	FG4ABAGBA	20	400

1.2 ELECTRIC CALCULATIONS

1.2.1 Voltage drops

Cross section of conductors is determined according to their electrical qualities. In general, the calculation will be based on the voltage drop "e" which should be less than 5%. Under normal operating conditions a temperature of 40^0 C of conductors is considered.

The following expression indicates the voltage drop between phases for three-phase circuits:

$$e = 10^3 \cdot \frac{R + X \cdot tg(\varphi)}{U} \cdot P \cdot L \; (V)$$

Expressed as a percentage:

$$e\,(\%) = 10^2 \cdot \frac{e}{U} = 10^5 \cdot \frac{R + X \cdot tg(\varphi)}{U^2} \cdot P \cdot L$$

Where:

- U, nominal voltage of the line.
- φ, phase difference angle.
- X, reactance Ω / km.
- $R, resistance$ Ω / km (40^0 C).

The relative voltage drop in % can be also expressed in the following way:

$$e\% = 100\frac{e}{U} = \frac{M}{M_1}$$

Being:

$$M = P \cdot L$$

P, three-phase active power (in kW), located at the distance L (in km) from the origin of the energy.

$$M_1 = \frac{1}{10^5} \cdot \frac{U^2}{R + X \cdot tg(\varphi)}$$

Table with the resistance for each cable (Ω/km) (40^0 C) [UNE 21030-1]

Phase cross section (mm^2)	Resistance 40^0 C (Ω / km)
25	1,345
50	0,718
95	0,359
150	0,231

For example:

- Phase cross section = 25 mm^2.

$$M_1 = \frac{1}{10^5} \cdot \frac{400^2}{1.345 + 0.1 \cdot 0.484} = 1.15\ kW \cdot km$$

Values of M1:

Phase cross section (mm^2)	M1 ($kW \cdot km$)
25	1,15
50	2,09
95	3,93
150	5,73

1.2.2 Simultaneity coefficient

We have a table of the simultaneity factor according to the number of users of each line. [Table 1, section 3.1, TC-BT-10]

Nº users	Simultaneity coefficient	Nº users	Simultaneity coefficient
1	1	12	9,9
2	2	13	10,6
3	3	14	11,3
4	3,8	15	11,9
5	4,6	16	12,5
6	5,4	17	13,1
7	6,2	18	13,7
8	7	19	14,3
9	7,8	20	14,8
10	8,5	21	15,3
11	9,2	n>21	15,3+(n-21)0,5

Now we are going to calculate the different voltage drops for the lines from the transformation centres to the end of line support. Knowing that the maximum can be of 5%.

As we have a milking parlour it`s consumption will be 18.4 kW [25]. It can be considered as two homes together.

This reference shows the average power of a parking milking after doing a study of many of them.

TRANSFORMATION CENTRE 1 (TC1)

Circuit 1 (kW)	Circuit 2 (kW)	Circuit 3 (kW)	Circuit 3 (kW)	Direct supplies (kW)	Sum	
115	109,48	9,2	49,68	27,6	310,96	kW
					345,51	kVA

We calculate as example the voltage drop between TC1-1, (conductor T-95).

$$M = P \cdot L = 115 \cdot 0.037 = 4.26\ kW \cdot km$$

$$M_1 = 3.93\ kW \cdot km$$

$$Voltage\ drop\ (\%) = \frac{M}{M_1} = \frac{4.26}{3.93} = 1.08\ \%$$

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
	CTI1-1	16	115	1,482	0,037	4,26	T - 95	3,93	1,08	1,08
1	1-2	13	97,52	1,8	0,045	4,39	T - 95	3,93	1,12	2,20
	2-3	4	34,96	1,8	0,045	1,57	T - 95	3,93	0,40	2,60

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
	TC1-1	15	109,48	1,6	0,04	4,38	T - 95	3,93	1,11	1,11
	1-2	9	71,76	1,65	0,041	2,96	T - 50	2,09	1,42	2,53
	2-3	7	57,04	1,8	0,045	2,57	T - 50	2,09	1,23	3,76
2	3-4	5	42,32	1,621	0,041	1,72	T - 50	2,09	0,82	4,58
	4-5	1	9,2	1,2	0,03	0,28	T - 50	2,09	0,13	4,71
	1-6	4	34,96	1,6	0,040	1,40	T - 25	1,15	1,22	2,33
	6-7	2	18,4	1,145	0,029	0,53	T - 25	1,15	0,46	2,79

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
3	TC1-1	1	9,2	1,2	0,03	0,28	T - 25	1,15	0,24	0,24

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
	TC1-1	6	49,68	1,8	0,045	2,24	T - 25	1,15	1,94	1,94
4	1-2	4	34,96	1,1	0,0275	0,96	T - 25	1,15	0,84	2,78
	2-4	3	27,6	1,8	0,045	1,24	T - 25	1,15	1,08	3,86

TRANSFORMATION CENTRE 2 (TC2)

Circuit 1 (kW)	Circuit 2 (kW)	Circuit 3 (kW)	Direct supplies (kW)	Sum	
149,96	49,68	97,52	27,6	324,76	kW
				360,84	kVA

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
1	TC2-1	23	149,96	1,515	0,038	5,68	T - 150	5,73	0,99	0,99
	1-2	21	140,76	1,45	0,036	5,1	T - 150	5,73	0,89	1,88
	2-3	10	78,2	1,313	0,033	2,57	T - 95	3,93	0,65	2,53
	3-4	5	42,32	1,8	0,045	1,9	T - 95	3,93	0,48	3,02
	4-5	2	18,4	1,8	0,045	0,83	T - 95	3,93	0,21	3,23
	5-7	1	9,2	2,482	0,062	0,57	T - 95	3,93	0,15	3,38
	2-9	6	49,68	2,923	0,073	3,63	T - 50	2,09	1,74	3,62
	9-10	3	27,6	1,43	0,036	0,99	T - 50	2,09	0,47	4,09
	10-11	1	9,2	0,729	0,018	0,17	T - 50	2,09	0,08	4,17

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
2	TC2-1	6	49,68	0,848	0,021	1,05	T - 25	1,15	0,92	0,92
	1-2	3	27,6	0,497	0,012	0,34	T - 25	1,15	0,30	1,21
	2-3	1	9,2	0,8	0,02	0,18	T - 25	1,15	0,16	1,37

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
3	TC2-1	13	97,52	1,7	0,043	4,14	T - 95	3,93	1,05	1,05
	1-2	12	91,08	1,749	0,044	3,98	T - 95	3,93	1,01	2,07
	2-3	9	71,76	1,7	0,043	3,05	T - 50	2,09	1,46	3,53
	3-4	6	49,68	1,5	0,038	1,86	T - 50	2,09	0,89	4,42
	2-5	3	27,6	1,8	0,045	1,24	T - 25	1,15	1,08	3,15

TRANSFORMATION CENTRE 3 (TC3)

Circuit 1 (kW)	Circuit 2 (kW)	Circuit 3 (kW)	Direct supplies (kW)	Sum	
57,04	109,48	154,56	0	321,08	kW
				356,76	kVA

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
1	TC3-1	7	57,04	1,8	0,045	2,57	T - 95	3,93	0,65	0,65
	1-4	5	42,32	5,4	0,135	5,71	T - 95	3,93	1,45	2,11
	4-8	4	34,96	5,083	0,127	4,44	T - 95	3,93	1,13	3,24
	8-9	2	18,4	1,8	0,045	0,83	T - 25	1,15	0,72	3,96
	9-10	1	9,2	1,8	0,045	0,41	T - 25	1,15	0,36	4,32
	8-11	2	18,4	1,316	0,033	0,61	T - 25	1,15	0,53	3,76

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
2	CTI3-2	15	109,48	3,445	0,086	9,43	T - 95	3,93	2,40	2,40
	2-3	5	42,32	1,5	0,038	1,59	T - 50	2,09	0,76	3,16
	3-4	3	27,6	1,323	0,033	0,91	T - 50	2,09	0,44	3,60
	4-5	2	18,4	1,8	0,045	0,83	T - 50	2,09	0,40	3,99
	5-6	1	9,2	1,5	0,038	0,35	T - 50	2,09	0,17	4,16
	2-7	9	71,76	1,8	0,045	3,23	T - 50	2,09	1,55	3,94
	7-8	5	42,32	1,8	0,045	1,9	T - 50	2,09	0,91	4,86
	8-9	1	9,2	1	0,025	0,23	T - 50	2,09	0,11	4,97

Circuit	Span	Nº Users	Power (kW)	Drawing length (cm)	Real length (km)	M	Conductor	M1	Voltage drop (%)	Accumulated voltage drop (%)
3	CTI3-1	24	154,56	1,8	0,045	6,96	T - 150	5,73	1,21	1,21
	1-2	22	145,36	1,8	0,045	6,54	T - 150	5,73	1,14	2,36
	2-3	19	131,56	1,8	0,045	5,92	T - 150	5,73	1,03	3,39
	3-5	6	49,68	2,3	0,058	2,86	T - 150	5,73	0,50	3,89
	5-6	5	42,32	1,693	0,042	1,79	T - 150	5,73	0,31	4,20
	6-7	4	34,96	1,8	0,045	1,57	T - 150	5,73	0,27	4,47
	7-9	2	18,4	1,781	0,045	0,82	T - 150	5,73	0,14	4,62
	3-10	7	57,04	1,8	0,045	2,57	T - 95	3,93	0,65	4,04
	10-11	5	42,32	1,8	0,036	1,52	T - 95	3,93	0,39	4,43
	11-12	2	18,4	0,512	0,0102	0,19	T - 95	3,93	0,05	4,48

1.2.3 Protections

In general, the conductors will be protected, against overloads and short circuits, by the fuse links existing at the head of the main line. But if this protection is not enough for the whole line they will also be installed at the beginning of the derivations.

These fuse links will be class "gG", according to [UNE-EN 60269-1].

1.2.3.1 PROTECTION AGAINST OVERLOADS

To protect in a proper way the line, a fuse must meet the following conditions. [Section 1.1, Guide -BT-22]

<u>CONDITION 1</u>

$$I_B \leq I_n \leq I_Z$$

This condition indicates physically that the fuse must let pass the necessary current to make the installation work according to the expected demand, but it must not allow a current to be reached that deteriorates the cable, specifically, its insulation, which is the weak part.

- I_B, operational current.

For a three-phase line:

$$I_B = \frac{P}{\sqrt{3} \cdot U \cdot \cos(\varphi)}$$

- I_Z, maximum admissible current.

For the different types of cables used, their maximum admissible currents at 40ºC: [Table 3, section 4.2.1.1, ITC-BT-06].

Conductors	
Composition of the cables	Iz (A)
3x25 Al/54,6 Alm	100
3x50 Al/54,6 Alm	150
3x95 Al/54,6 Alm	230
3x150 Al/80 Alm	305

- I_n, fuse nominal current.

The nominal current varies between 2 A-1250 A according to [DF electric catalogue]

CONDITION 2

$$I_f \leq 1.45 I_Z$$

This inequality expresses that the cables can withstand transient (non-permanent) overloads without deteriorating up to 145% of the maximum thermally admissible current and only then the fuses have to act, melting when, during conventional time the fusion current is maintained.

- I_f, current that ensures the performance of the fuse.

I_f can take different values, [UNE EN 269-1]

In (A)	Conventional time (h)	If
In ≤ 4	1	2,1 In
4 < In ≤ 16	1	1,9 In
16 < In ≤63	1	1,6 In
63 < In ≤ 160	2	1,6 In
160 < In ≤ 400	3	1,6 In
400 < In	4	1,6 In

So, in our case, we will have:

$$I_B \leq I_n \leq I_Z$$

$$1.6 I_n \leq 1.45 I_Z$$

1.2.3.2 PROTECTION AGAINST SHORT-CIRCUITS

The "gG" fuse links, dimensioned against overloads, will protect the conductors against short circuits, based on the following considerations: [Section 1.1, Guide -BT-22]

- Its breaking capacity will be greater, at the point where they are installed, than the value of the expected short-circuit current.

- Any short circuit current, which occurs at any point in the network, must be interrupted in a time shorter than that which would lead the conductor to reach its limit temperature ,250ºC. Temperature given by manufacturer [Prysmian Group catalogue]

For short-circuits lasting no longer than 5 seconds, the time "t" in which a short-circuit current raises the temperature of the conductor from its maximum admissible temperature, in normal operation, up to the admissible limit temperature, can be calculated, in a first approximation, by the formula:

$$I^2{}_{sc} \cdot t = K^2 \cdot S^2$$

From where:

$$\sqrt{t} = K \cdot \frac{S}{I_{sc}}$$

- Isc = Effective value of the short-circuit current [A] according to [Table 3 of UNE-EN 602691]

- K = Constant that depends on the nature of the conductor and its insulation. This value, for aluminium conductors with cross-linked polyethylene insulation, is 93. [Prysmian group catalogue]

- S = Section of the phase conductor [mm2]

1.2.4 Maximum short-circuit current

It is the current that does not cause any decrease in the mechanical characteristics of the conductors, even after a high number of short circuits.

The maximum short-circuit current for an S-section conductor is determined by the expression:

$$I_{sc} = 93 \cdot S \cdot \sqrt{\frac{1}{t}}$$

Being "t" the time in seconds of the duration of the short circuit and S the section in mm^2.

The following short-circuit currents in (kA) are obtained, for cables RZ 0.6/1 kV:

For example:

- Cross section 95 mm^2.
- Short-circuit duration, 0.2 s.

$$I_{sc} = 93 \cdot 95 \cdot \sqrt{\frac{1}{0.2}} = 19.76\ kA$$

Cable C cross section mm2	Short circuit current (kA)								
	Short circuit duration (s)								
	0,1	0,2	0,3	0,5	1	1,5	2	2,5	3
25	7,35	5,20	4,24	3,29	2,33	1,90	1,64	1,47	1,34
50	14,70	10,40	8,49	6,58	4,65	3,80	3,29	2,94	2,68
95	27,94	19,76	16,13	12,49	8,84	7,21	6,25	5,59	5,10
150	44,11	31,19	25,47	19,73	13,95	11,39	9,86	8,82	8,05
Density A/mm2	294	208	170	132	93	76	66	59	54

The short-circuit current is limited by the impedance of the circuit to the short-circuit point.

For a fault between phase and neutral, considered as more unfavourable, the short-circuit current Isc is given by the following expression:

$$I_{sc} = \frac{U}{Z} = \frac{c \cdot U}{\sqrt{[L \cdot (R_p + R_n)]^2 + [L \cdot (X_p + X_n)]^2}}$$

Where:

- U = Simple voltage, in normal operation, at the point where the protection fuse is located [V]
- L = Line length from the fuse to the short-circuit point [km]
- R_f = Resistance of the phase conductor at the temperature of 20 ºC, [Ω / km]
- R_n = Resistance of the neutral conductor at a temperature of 20 ºC [Ω / km]
- X_f = Reactance of the phase conductor [Ω / km]
- X_n = Neutral conductor reactance [Ω / km]
- c = Voltage factor, according to [UNE 60909-0], that for Low Voltage networks its value is 0.95.

It is established as protection criterion against short-circuit of a cable fed by a transformer and protected by a determined fuse that the maximum duration of a single-phase short circuit at the farthest end of the line is 5 seconds, fulfilling the protection conditions indicated above.

Since the current of the postulated short circuit decreases with increasing line length, and on the other hand the operating time of the fuse increases as the short circuit current decreases, there will be a maximum line length above which the established protection criteria will not be met.

$$I_{sc(5)} = \frac{c \cdot U}{Z} = \frac{c \cdot U}{\sqrt{[L_{max} \cdot 1.5 \cdot (R_p + R_n)]^2 + [L_{max} \cdot (X_p + X_n)]^2}}$$

Where:

- Isc (5) = Current corresponding to 5 seconds in the fuse according to i-t characteristics. [DF electric catalogue]
- Lmax = Maximum protected line length [km].

Below we have a table in which we can see the maximum length of conductor that a fuse can protect taking into account its nominal current and the type of conductor.

Example for cable (T-50), fuse (I_n=63 A):

- $I_{sc(5)}$= 230 A
- $c = 0.95$
- U = 230 V
- $R_p = 0.641$ Ω/km
- $R_n = 0.63$ Ω/km
- $X_p = 0.1$ Ω/km
- $X_n = 0.1$ Ω/km

Using this data, we obtain $L_{max} = 491\ m$

Cable	Fuse (A)	Lmax (m)
T-25	16	1725
	32	635
	63	343
	80	249
	100	188
T-50	63	491
	80	357
	100	270
	125	205
T-95	63	652
	80	473
	100	358
	125	272
	160	219
	200	157
T-150	63	950
	80	689
	100	520
	125	395
	160	318
	200	227
	250	181

When the derivations of a main line are made with cross sections lower than that of the one, the maximum length of derivation that can be protected against short circuits, $Lmax_2$, by the same fuse that protects the main line, is one in which the following expression is fulfilled:

$$Z_{Lmax2} = Z_{Lmax1-d1}$$

$$Z_{Lmax2} = \sqrt{L^2{}_{max2} * [1.5 * (R_{p2} + R_{n2})]^2 + L^2{}_{max2} * (X_{p2} + X_{n2})^2}$$

$$Z_{Lmax1-d1} = \sqrt{(L_{max1} - d_1)^2 * [1.5 * (R_{p1} + R_{n1})]^2 + (L_{max1} - d_1)^2 * (X_{p1} + X_{n1})^2}$$

Where:

- L_{max1} = Maximum length of the main line that can be protected.
- L_{max2} = Maximum protected length of derived line.
- d1 = Length from the start of the main line to the point of derivation.

For example, for the derivation line 1-5 of the circuit 2 of transformation centre 1:

- Main line cable, T-95.
- $I_{Bmax} = 175.58\ A$
- $I_{n(fuse)} = 200\ A$
- $L_{max1} = 157\ m$
- $R_{p1} = 0.32$ Ω/km
- $R_{n1} = 0.63$ Ω/km
- $X_{p1} = 0.1$ Ω/km
- $X_{n1} = 0.1$ Ω/km
- $d_1 = 40\ m$
- Derivation cable, T-50.
- $R_{fp2} = 0.641$ Ω/km
- $R_{n2} = 0.63$ Ω/km
- $X_{p2} = 0.1$ Ω/km
- $X_{n2} = 0.1$ Ω/km

We obtain that L_{max2} = 87.83 m < $L_{1-5} = 157\ m$

So we have to protect the derivation line using another fuse.

Below we have tables corresponding to the fuses used to protect each main line and derivation:

TRANSFORMATION CENTRE 1

Section	Cable	Ibmax (A)	In (A)	Iz (A)	Lmax1 (m)	Total length (m)	Lmax2 (m)	R (Ω)	X (Ω)
TC1-3	T-95	184,43	200	230	157	127,05		0,1207	0,0254
TC1-1	T-95	175,58	200	230	157	40		0,0380	0,0080
1-5	T-50	115,08	125	150	205	157	87,83	0,1995	0,0314
1-7	T-25	56,07	63	100	343	68,63	61,17	0,1256	0,0137
TC1-1	T-25	14,75	16	100	343	1725		0,0549	0,0060
TC1-4	T-25	79,67	80	100	249	117,5		0,2150	0,0235

TRANSFORMATION CENTRE 2

Circuit	Section	Cable	Ibmax (A)	In (A)	Iz (A)	Lmax1 (m)	Total length (m)	Lmax2 (m)	R (Ω)	X (Ω)
1	TC2-2	T-150	240,50	250	305	181	74,13		0,0471	0,0148
	2-7	T-95	125,41	160	230	219	184,88	72,39	0,1756	0,0370
	2-11	T-50	79,67	80	150	357	127,05	54,34	0,1615	0,0254
2	TC2-3	T-25	79,67	80	100	249	53,63		0,0981	0,0107
3	TC2-2	T-95	156,40	160	230	219	86,23		0,0819	0,0172
	2-4	T-50	115,09	No needed	150		80	99,66	0,1017	0,0160
	2-5	T-25	44,26	No needed	100		45	69,42	0,0824	0,0090

TRANSFORMATION CENTRE 3

Circuit	Section	Conductor	Ibmax (A)	In (A)	Iz (A)	Lmax1 (m)	Total length (m)	Lmax2 (m)	R (Ω)	X (Ω)
1	TC3-8	T-95	91,48	100	230	358	307,075		0,2917	0,0614
	8-10	T-25	29,51	32	100	343	90	26,63	0,1647	0,0180
	8-11	T-25	29,51	32	100	343	32,9	26,63	0,0602	0,0066
2	TC3-2	T-95	175,58	200	230	157	86,13		0,0818	0,0172
	2-6	T-50	67,87	80	150	357	153,08	53,2	0,1946	0,0306
	2-9	T-50	115,09	125	150	205	115	53,2	0,1462	0,0230
3	TC3-3	T-150	247,88	250	305	181	135		0,0859	0,0270
	3-5	T-150	79,67	80	305	689	189,35	46	0,1204	0,0379
	3-10	T-95	91,48	100	230	358	91,24	31,16	0,0867	0,0182

Next, we will check the following conditions, to know if the fuses are suitable:

- Its breaking capacity will be greater, at the point where they are installed, than the value of the expected maximum short-circuit current.

Since we have a maximum short-circuit current of 44.11 kA (T-150) for a time of 0.1 seconds, we must choose fuses with higher breaking capacity than this short-circuit current.

Looking in the DF electric catalogue we can find 120 kA breaking capacity fuses.

- The fuse must react to the minimum short-circuit current at the end of the line in less than 5 seconds.

- The fuse must react at the maximum short circuit current before it damages the conductors.

This maximum short circuit current is considered for t=0.1s.

These two conditions are going to be checked in a table in which we will also add manual operation disconnectors. [ABB catalogue]

To be able to carry out operations on the line. They will be installed at the beginning of each line and chosen according to its nominal intensity and voltage (415 V).

Example for transformation centre 1, circuit 1. Cable (T-95), fuse (I_n=200 A):

- $c = 0.95$
- U = 230 V
- $R_p = 0.32$ Ω/km
- $R_n = 0.63$ Ω/km
- $X_p = 0.1$ Ω/km
- $X_n = 0.1$ Ω/km
- $L = 127.05$ m

Second condition:

$$I_{sc} = \frac{U}{Z} = \frac{c \cdot U}{\sqrt{[L \cdot (R_p + R_n)]^2 + [L \cdot (X_p + X_n)]^2}}$$

$$I_{scmin} = \frac{0.95 \cdot 230}{\sqrt{[0.12705 \cdot (0.32 + 0.63)]^2 + [0.12705 \cdot (0.1 + 0.1)]^2}} = 1771.48\ A$$

On i-t characteristics we can see that for a time of 5 seconds, I_f= 1010 A

$$I_{f(5)} < I_{scmin}$$

Third condition

- $I_{scmax\ (t=0.1s)} = 27.94\ kA$

On i-t characteristics we can see that for a time of 0.1 seconds, I_f= 2900 A.

$$I_{f(0.1)} < I_{scmax}$$

Therefore, the fuse works properly.

Transformation centre 1

Circuit	Section	Conductor	In (A)	Total length (m)	Phase resistence (Ω/km)	Neutral resistance (Ω/km)	Icc min (A)	If (t=5s) (A)	Icc max (kA)	If (t=0,1s) (A)	Disconnector	Indis (A)
1	TC1-3	T-95	200	127,05	0,32	0,63	1771,48	1010	27,94	2900	OT200E	200
2	TC1-1	T-95	200	40	0,32	0,63	5626,66	1010	27,94	2900	OT200E	200
	1-5	T-50	125	157	0,641	0,63	1081,67	510	14,7	1060		
	1-7	T-25	63	68,63	1,2	0,63	1729,45	230	7,35	530		
3	TC1-1	T-25	16	30	1,2	0,63	3956,41	230	7,35	100	OT16F	16
4	TC1-4	T-25	80	117,5	1,2	0,63	1010,15	350	7,35	800	OT80F	80

Transformation centre 2

Circuit	Section	Conductor	In (A)	Total length (m)	Phase resistence	Neutral resistance	Icc min (A)	If (t=5s) (A)	Icc max (kA)	If (t=0,1s) (A)	Disconnector	Indis (A)
1	TC2-2	T-150	250	74,13	0,206	0,43	4421,03	1050	44,11	4000	OT250E	250
	2-7	T-95	160	184,88	0,32	0,63	1217,37	780	27,94	1085		
	2-11	T-50	80	127,05	0,641	0,63	1336,66	350	14,7	800		
2	TC2-3	T-25	80	53,63	1,2	0,63	2213,17	350	7,35	800	OT80F	80
3	TC2-2	T-95	160	86,23	0,32	0,63	2610,07	780	27,94	1085	OT160EV	160
	2-4	T-50	No	80	0,641	0,63	2122,78		14,7			
	2-5	T-25	No	45	1,2	0,63	2637,60		7,35			

Transformation centre 3

Circuit	Section	Conductor	In (A)	Total length	Phase resistence	Neutral resistance	Icc min (A)	If (t=5s) (A)	Icc max (kA)	If (t=0,1s) (A)	Disconnector	Indis (A)
1	TC3-8	T-95	100	307,075	0,32	0,63	732,94	450	27,94	1025	OT100F	100
	8-10	T-25	32	90	1,2	0,63	1318,80	230	7,35	250		
	8-11	T-25	32	32,9	1,2	0,63	3607,66	230	7,35	250		
2	TC3-2	T-95	200	86,13	0,32	0,63	2613,10	1010	27,94	2900	OT200E	200
	2-6	T-50	80	153,08	0,641	0,63	1109,37	350	14,7	800		
	2-9	T-50	125	115	0,641	0,63	1476,72	510	14,7	1060		
3	TC3-3	T-150	250	135	0,206	0,43	2427,64	1050	44,11	4000	0T250E	250
	3-5	T-150	80	189,35	0,206	0,43	1730,82	350	44,11	800		
	3-10	T-95	100	91,24	0,32	0,63	2466,75	450	27,94	900		

1.2.5 Earthing

In order to limit the voltage that can occur with respect to earth, the neutral conductor will be grounded: [ITC BT]

- In the proximity of the transformation centre, in the first support of each one of the overhead lines.
- At judiciously chosen points, taking into account the nature of the land, so that the average number of earth points on the lines of the same transformation centre is not greater than one for each 500 meters of line length. They will be arranged preferably in the area where the derivations are and in all end-of-line supports.

1.3 MECHANICAL CALCULATION

1.3.1 Mechanical calculations of supports

The supports will be dimensioned according to the calculation hypotheses established for the conductors in the Low Voltage Electrotechnical Regulation for Zone A. [Section 2.3, ITC BT-06].

Vibrated concrete supports of 9 meters high will be used according to the [UNE 207016: 2007] standard.

The column on the left indicates the height, 9 meters, and the maximum nominal force that can hold up the support.

The nominal values are:

- 9/160
- 9/250
- 9/400
- 9/630
- 9/850
- 9/1000
- 9/1600

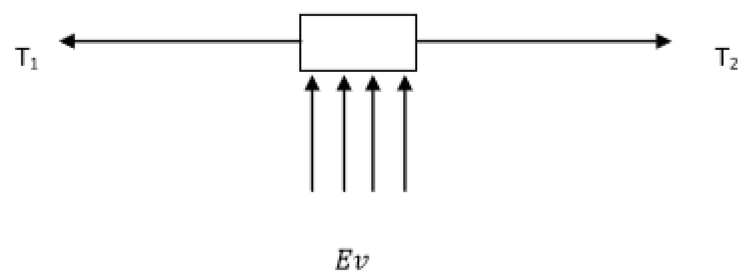
The supports will be classified according to their function in:

- Intermediate supports
- Angle supports
- Derivation supports
- End of line supports

Now let's describe the formulas to determine the efforts on the supports depending on the type.

1.3.1.1 INTERMEDIATE SUPPORT

Permanent loads and unbalance of tensions have very little influence, so only forces due to wind load on the conductors are considered.

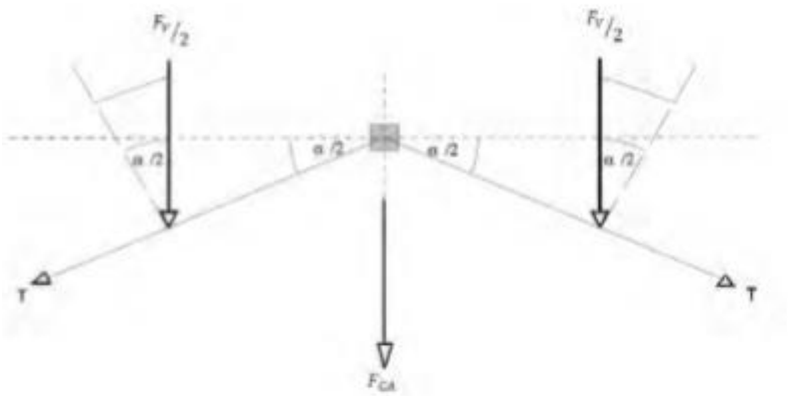


$$F_v = p_w \cdot \emptyset \cdot \frac{a+b}{2}\ (daN)$$

- p_w, wind pressure, in Zone A p_w= 50 daN/m^2
- $\emptyset$, cable diameter (m)
- a, previous span (m)
- b, following span (m)

1.3.1.2 ANGLE SUPPORT

Forces due to wind and tension of conductors are considered.



$$F_A = 2 \cdot T_{max} \cdot sin\left(\frac{\alpha}{2}\right) \text{ (daN)}$$

$$F_V = p_w \cdot \emptyset \cdot \frac{a+b}{2} \cdot cos^2\left(\frac{\alpha}{2}\right) \text{ (daN)}$$

$$F = F_A + F_V = 2 \cdot T_{max} \cdot sin\left(\frac{\alpha}{2}\right) + p_w \cdot \emptyset \cdot \frac{a+b}{2} \cdot cos^2\left(\frac{\alpha}{2}\right)\ (daN)$$

- T_{max}, maximum tension of conductors. In our case T = 500 daN.
- α, line deviation angle.
- p_w, wind pressure, in Zone A p_w= 50 daN/m^2
- Ø, cable diameter (m)
- a, previous span (m)
- b, following span (m)

1.3.1.3 END OF LINE SUPPORTS

Forces due to wind and tension of the conductor are considered.

$$F_v = p_w \cdot \emptyset \cdot \frac{a}{2} \ (daN)$$

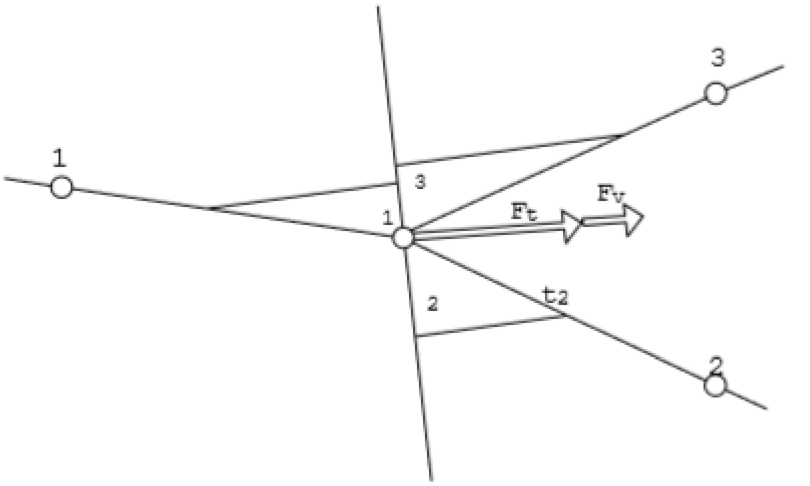
$$F_T = T_{max} \ (daN)$$

$$F = \sqrt{F_v{}^2 + F_T{}^2} \ (daN)$$

- T_{max}, maximum tension of conductors.
- p_w, wind pressure, in Zone A p_w= 50 daN/m^2
- Ø, cable diameter (m).
- a, span (m).

1.3.1.4 DERIVATION SUPPORTS

It is recommended to adopt the graphic calculation for its extreme simplicity.



To the resultant of tensions, we will add in absolute value the force due to the wind pressure of 50 daN / m2 applied to the projection of the spans on a perpendicular to the resultant of the tensions, to obtain the total.

The support will be oriented in the direction of the resultant.

1.3.2 Results

The diameters of the different cable are:

Cable	Diameter (mm)
T-25	23,05
T-50	30,25
T-95	40,5
T-150	49,37

Example of calculation:

- Intermediate support, (Transformation centre 2, circuit 1, support 4)

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
4	Intermediate	45	T-95	45	T-95	180	0	91,13	9/160

$$F_v = p_w \cdot \emptyset \cdot \frac{a+b}{2}\ (daN)$$

$$F_v = 50 \cdot 40.5 \cdot 10^{-3} \cdot \frac{45+45}{2} = 91.13\ daN$$

- Angle support, (Transformation centre 1, circuit 1, support 1)

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Angle	37	T-95	45	T-95	174	6	135.13	9/160

$$F = F_A + F_V = 2 \cdot T_{max} \cdot sin\left(\frac{\alpha}{2}\right) + p_w \cdot \emptyset \cdot \frac{a+b}{2} \cdot cos^2\left(\frac{\alpha}{2}\right)\ (daN)$$

$$F = 2 \cdot 500 \cdot sin\left(\frac{6}{2}\right) + 50 \cdot 40.5 \cdot 10^{-3} \cdot \frac{37+45}{2} \cdot cos^2\left(\frac{6}{2}\right) = 135.13\ daN$$

- End of line, (Transformation centre 1, circuit 1, support 3)

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
3	End of line	45	T-95					502,07	9/630

$$F_v = p_w \cdot \emptyset \cdot \frac{a}{2}\ (daN)$$

$$F_v = 50 \cdot 40.5 \cdot 10^{-3} \cdot \frac{45}{2} = 45.56\ daN$$

$$F_T = T_{max} = 500\ daN$$

$$F = \sqrt{45.56^2 + 500^2} = 502.07\ daN$$

Calculation of derivation support will be attached in the annex.

TRANSFORMATION CENTRE 1

Circuit 1

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
TC1	Derivation 1							239,32	9/400
1	Angle	37	T-95	45	T-95	174	6	135,13	9/160
2	Angle	45	T-95	45	T-95	159	21	270,33	9/400
3	End of line	45	T-95					502,07	9/630

Circuit 2

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Derivation 2							502,59	9/630
2	Angle	41	T-50	45	T-50	162	18	219,88	9/250
3	Angle	45	T-50	41	T-50	129	51	483,49	9/630
4	Angle	41	T-50	30	T-50	125	55	503,99	9/630
5	End of line	30	T-50					500,51	9/630
6	Angle	40	T-25	29	T-25	172	8	109,32	9/160
7	End of line	29	T-25					500,28	9/630

Circuit 3

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	End of line	30	T-25					500,30	9/630

Circuit 4

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Angle	45	T-25	28	T-25	173	7	102,96	9/160
2	Angle	28	T-25	20	T-25	126	54	475,95	9/630
3	Angle	20	T-25	25	T-25	123	57	497,19	9/630
4	End of line	25	T-25					500,21	9/630

TRANSFORMATION CENTRE 2

Circuit 1

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
TC2	Derivation 3							723,75	9/850
1	Angle	38	T-150	36	T-150	147	33	367,98	9/400
2	Derivation 4							212,81	9/250
3	Angle	33	T-95	45	T-95	160	20	250,24	9/400
4	Intermediate	45	T-95	45	T-95	180	0	91,13	9/160
5	Intermediate	45	T-95	29,55	T-95	180	0	75,48	9/160
6	Angle	29,55	T-95	32,5	T-95	94	86	520,05	9/630
7	End of line	32,5	T-95					501,08	9/630
8	Angle	28,08	T-50	45	T-50	125	55	505,23	9/630
9	Angle	45	T-50	36	T-50	124	56	517,23	9/630
10	Angle	36	T-50	18	T-50	126	54	486,41	9/630
11	End of line	18	T-50					500,19	9/630

Circuit 2

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Angle	21	T-25	12	T-25	134	46	406,84	9/630
2	Angle	12	T-25	20	T-25	158	22	208.58	9/250
3	End of line	20	T-25					500,13	9/630

Circuit 3

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Angle	43	T-95	44	T-95	144	36	414,15	9/630
2	Derivation 5							414,15	9/630
3	Angle	43	T-50	38	T-50	150	30	315,97	9/400
4	End of line	38	T-50					500,83	9/630
5	End of line	45	T-25					500,67	9/630

TRANSFORMATION CENTRE 3

Circuit 1

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
TC3	Derivation 6							612,34	9/630
1	Intermediate	45	T-95	45	T-95	180	0	91,13	9/160
2	Intermediate	45	T-95	45	T-95	180	0	91,13	9/160
3	Intermediate	45	T-95	45	T-95	180	0	91,13	9/160
4	Intermediate	45	T-95	30	T-95	180	0	75,94	9/160
5	Intermediate	30	T-95	33,75	T-95	180	0	64,55	9/160
6	Angle	33,75	T-95	35	T-95	93	87	724,98	9/850
7	Intermediate	35	T-95	28,33	T-95	180	0	64,12	9/160
8	Derivation 7							509,38	9/630
9	Intermediate	45	T-25	45	T-25	180	0	51,86	9/160
10	End of line	45	T-25					500,67	9/630
11	End of line	33	T-25					500,36	9/630

Circuit 2

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Intermediate	45	T-95	41,08	T-95	180	0	87,16	9/160
2	Derivation 8							297,88	9/400
3	Angle	38	T-50	33	T-50	144	36	357,58	9/400
4	Angle	33	T-50	45	T-50	91	89	730,92	9/850
5	Angle	45	T-50	38	T-50	172	8	132,22	9/160
6	End of line	38	T-50					500,83	9/630
7	Intermediate	45	T-50	45	T-50	180	0	68,06	9/160
8	Intermediate	45	T-50	25	T-50	180	0	52,94	9/160
9	End of line	25	T-50					500,36	9/630

Circuit 3

Support		Previous span		Following span		Angle	Deviation angle	Resultant force (daN)	Support
Number	Type	Length (m)	Conductor	Length (m)	Conductor				
1	Intermediate	45	T-150	45	T-150	180	0	111,08	9/160
2	Intermediate	45	T-150	45	T-150	180	0	111,08	9/160
3	Derivation 9							591,76	9/630
4	Angle	27,5	T-150	30	T-150	116	64	580,96	9/630
5	Angle	30	T-150	42	T-150	135	45	458,54	9/630
6	Angle	42	T-150	45	T-150	103	77	688,28	9/850
7	Angle	45	T-150	19,33	T-150	168	12	183,06	9/250
8	Angle	19,33	T-150	25	T-150	119	61	548,16	9/630
9	End of line	25	T-150					500,95	9/630
10	Angle	45	T-95	36	T-95	177	3	108,13	9/160
11	Angle	36	T-95	10	T-95	44	136	933,72	9/1000
12	End of line	10	T-95					500,10	9/630

2. MIDDLE VOLTAGE OVERHEAD LINE

2.1 INTRODUCTION

We will have two lines which start in a bigger transformation centre at the end of the village, one of them will feed the transformation centre TC1 and TC2 and the other to TC3.

2.1.1 Nominal voltage

The normalized nominal voltages (U_n) and the highest voltages of the network (U_s) are defined in [section 1.2 of ITC-LAT 07 of the R.L.A.T]. In our case U_n=20 kV and U_s=24 kV

2.1.2 Line category

High voltage overhead lines, according to what is established in [article 3 of the R.L.A.T.], will be classified, according to their nominal voltage, in the following categories:

- Especial category, $U_n \geq 220$ kV
- First category, 66 kV $< U_n < 220$ kV
- Second category, 30 kV $< U_n \leq 66$ kV
- Third category, 1 kV $< U_n \leq 30$ kV

In our case it is third category (20 kV)

2.1.3 Zone by altitude

Three different zones are determined for the electric lines according to the altitude at which they are located: [Section 3.1.3 of ITC-LAT 07 of the RLAT]

- Zone A, located less than 500 meters above sea level.
- Zone B, located at an altitude between 500 and 1000 meters above sea level.
- Zone C, located at more than 1000 meters above sea level.

Summary of the characteristics:

Nominal voltage (U_n)	20 Kv
Highest network voltage (U_s)	24 Kv
Network category	3ª
Altitude	Zone A (0-500m)
Nº of three phase circuits	1
Supports	Lattice galvanized metal
Conductor	47-AL1/8-ST1A (LA 56)
Frequency	50 Hz
Power factor	0,9

2.1.4 Conductor

As we will justify in the calculations we use the conductor 47-AL1/8-ST1A (LA 56). [UNE-EN 50182:2002 and UNE-EN 50182 CORR.:2005]

It is a plain conductor, made of aluminium with core of galvanize steel.

In the following table are shown its main characteristics. [UNE-EN 50182]

Cross section (mm^2)	Aluminium (AL1)	46,8
	Steel (ST1A)	7,79
	Total (AL1/ST1A)	54,6
Diameter (mm)	Core	3,15
	Total	9,45
Aluminium wires	Nº	6
	Diameter (mm)	3,15
Steel wires	Nº	1
	Diameter (mm)	3,15
Ultimate strength (daN)		1629
Mass per length unit (kg/km)		189,1
Elasticity module (kg/mm^2) (E)		8100
Linear strain coefficient (mm x 10^-6) (δ)		19,1

The maximum admissible temperature in the conductors, under normal load on the line, will not exceed 85 ° C. [section 2.1.1.3 Guide ITC-LAT-07]

2.1.5 Supports

We will use supports of lattice structure made of galvanized metal type “C” according to [UNE 207017]

This type of support consists of:

- Head: Upper part of the support, whose quadrangular prismatic shape of identical faces, structure, dimensions and holes remain fixed for all the supports of the same series.
- Support body: of truncated-pyramidal shape and square base.

All ferrous materials will be protected against oxidation by hot galvanizing according to UNE-EN ISO 1461.

The supports are used to hold the line conductors and to keep them at a safe distance from the ground indicated by the terrain.

According to [section 2.4 of ITC-LAT 07]:

- The conductors of the line will be fixed by means of insulators and ground cables directly to the support structure.
- The materials used must have a high resistance to the action of atmospheric agents, and if they do not present themselves, they should receive the appropriate protective treatments for this purpose.

CLASSIFICATION OF SUPPORT ACCORDING TO THEIR FUNCTION [section 2.4 of RLAT]

- Considering the type of insulation set and its function in the line, the supports are classified as:
  - Suspension support: Support with suspension sets.
  - Tension support: Support with tension sets.
  - Start or end of line supports: They are the first and last supports of the line, with tension sets, destined to support, in a longitudinal direction, the loads of the complete bundle of conductors.
  - Special supports: are those that have a function different from those defined in the previous classification.
- Considering their relative position with respect to the line direction, the supports are classified as:
  - Intermediate support.
  - Angle support.

2.1.6 Insulators

We will use glass insulators. Depending on the nominal voltage of the line, a type of insulator will be used. In our case we will use:

- U70BS, for nominal voltages up to 20kV. [section 4.4 ITC-LAT 07]

Whose characteristics will be described later.

2.1.7 Ironworks

Conductors shall be fixed to the supports by means of polymer or glass insulator chains, of the following type:

- Suspension set, they will be used in intermediate supports.
- Tension set, they will be used in angle, start and end of line supports.

The elements that make up the sets are in accordance with the formation of sets by cap and pin insulators and the [UNE 61466] standard of elements of insulator chains for overhead lines with nominal voltage higher than 1 kV. The different ironworks must comply with the provisions of [UNE 21006 and UNE-EN 61284].

All ironworks that form the insulation sets will have a mechanical safety coefficient greater than 3 with respect to their minimum breaking load, according to [section 3.3 of ITC-LAT 07].

2.1.8 Grounding of supports

The design of earthing meets the requirements indicated in [section 7 of ITC-LAT 07], that is:

- Resists mechanical efforts and corrosion according to section 7.3.2.
- Resists from a thermal point of view, the highest fault current section 7.3.3.
- Ensure safety of people respect to voltages that appear during a ground fault in the earthing systems, according to section 7.3.4.
- Protect from damages to equipment and guarantee the reliability of the line, as indicated in section 7.3.5.

Earthing of the metallic supports will be made connected to ground the structure of the supports located in areas of public attendance and those that contain switches or other operation devices.

We will proceed to the placement of the pikes forming a square around the support, respecting the minimum distances, united by a horizontal conductor.

Pikes 1.5 m length and 14.6 mm in diameter will be used, the copper conductor will be 50 mm2.

2.1.9 Insulation levels

The insulation level is defined by the voltages supported under rain, at 50 Hz, for one minute and with an impulse wave of 1.2 / 50 microseconds, according to the standards of the [International Electrotechnical Commission].

The minimum insulation levels corresponding to the highest voltage of the line, as defined above, are reflected in the table corresponding to [section 4.4. of ITC-LAT 07 of the RLAT].

The line analysed in this project has a maximum voltage U_s = 24 kV.

Highest voltage Us (kV)	Normalized short duration withstand voltage at industrial frequency (kV)	Normalized withstand voltage to lightning impulses (kV)
24	50	95
		125
		145

- Degree of insulation

The degree of insulation is the relation between the length of the creepage distance of an insulator (or the total of the set) and the phase voltage.

Degree of insulation recommended according to the zones crossed by the line: [table 14, section 4, guide ITC-LAT 07]:

Zones	Degree of insulation (mm/kV)
Forestal and agricultural	17-20
Industrial and close to sea	22-25
Chemical products factories	26-32
Thermal power stations	>32

In our case we choose the most unfavourable case for agricultural and forestall areas (20 mm/kV)

The formula of the degree of insulation is the following:

$$ID = \frac{n \cdot CD}{U_S}$$

Where:

- n, number of insulators of the insulator string.
- CD, creepage distance (mm)
- U_S, highest voltage of the line (kV)

We will use the insulator U 70BS whose mechanical characteristics are: [INAEL catalogue]

Material	Ultimate strength (daN)	Maximum nominal diameter of the insulating part D (mm)	Nominal spacing (mm)	Nominal creepage distance (mm)	Pin diameter (mm)
Toughened glass	7000	255	127	295	16

Electrical characteristics:

Withstand voltage at industrial frequency		Withstand voltage to lightning impulses (kV)
Dry (kV)	Raining (kV)	
70	45	90

Using the previous formula, we can calculate the number of insulators that we need:

$$n = \frac{ID \cdot U_S}{CD} = \frac{20 \cdot 24}{295} = 1.62\ insulators$$

So, we will use 2 insulators.

Design of sets.

- Tension set

Is composed of:

[MADE catalogue]

ELEMENT	AMOUNT	TYPE	WEIGHT (kg)
Ball Y-Clevis	1	HB-16	0,76
Insulator	2	U 70 BS	3,4
Strain clamp	1	GA-1/1	0,65
Socket eye	1	R-16	0,58
		Total (kg)	8,79

- Suspension set

Is composed of:

[MADE catalogue]

ELEMENT	AMOUNT	TYPE	WEIGHT (kg)
Ball Y-Clevis	1	HB-16	0,76
Insulator	2	U 70 BS	3,4
Suspension clamp	1	GAS	1,365
Horn holder socket eye	1	R-16-P	0,86
		Total (kg)	9,785

The length is approximately L=0.6 m.

- Mechanical calculation

In [section 3.4 of ITC-LAT 07 of the R.L.A.T], the considerations for the mechanical calculation of the insulators are indicated.

The standard of failure will be the breakage and loss of its insulating qualities, when subjected simultaneously to electrical voltage and mechanical force.

The mechanical safety coefficient shall not be less than 3.

$$\frac{US}{P_s} \geq 3$$

Where:

- US, ultimate strength of the part of the chain with least mechanical resistance.
- P_s, sum of mechanical forces

Assuming the most unfavourable situation, the longest span, therefore, more conductor weight to support, we obtain the following results:

- Longest span, 155 m
- Ultimate strength of Strain clamp GA-1/1 =3571.43 kg
- Weight of one phase conductor:

$$P = P_T \cdot L = 0.596 \cdot 155 = 92.38\ kg$$

- Insulator set weight, 9.785 kg.

$$P_S = 92.38 + 8.79 = 101.17\ kg$$

$$\frac{US}{P_s} = \frac{3571.43}{101.17} = 35.3 \geq 3$$

Therefore, the safety factor is met.

2.1.10 Safety distances

In electrical lines it is necessary to distinguish between internal and external distances.

The internal ones are only given to design a line with an acceptable capacity to resist overvoltage.

The external distances are used to determine the safety distances between the conductors and the objects below or in the vicinity of the line. Its objective is to avoid the damage of electric discharges to people.

- Distances of electrical insulation to avoid discharges.

Three types of electrical distances are considered, in according to [ITC-LAT 07 section 5.2]:

  - D_{el}, minimum insulation air distance, to prevent a disruptive discharge between phase conductors and objects at ground potential during overvoltages. It can be internal (distances from the conductor to the structure of the support) or external (distance from the conductor to an obstacle).

- D_{PP}, minimum insulation air distance, to prevent a disruptive discharge between phase conductors during overvoltages. It is an internal distance.

The values of Del and Dpp, as a function of the highest voltage of the line U_s will be indicated in the following table: [table 15 section 5.2 ITC-LAT 07].

Highest line voltage Us (kV)	Del (m)	Dpp (m)
24	0,22	0,25

- Distances between conductors

According to [section 5.4.1 of ITC-LAT-07 of RLAT].

It must be such that there is no risk of short-circuit between phases, keeping in mind the effects of oscillations of the conductors due to the wind.

$$D = K \cdot \sqrt{F + L} + K' \cdot D_{PP}$$

Where:

- D, separation between phase conductors of the same circuit or of different circuits, in meters.
- K, coefficient that depends on the oscillation of the conductors: [table 16, section 5.4.1, ITC-LAT-07]

Conductor	Maximum sag due to temperature or ice	Maximum sag due to wind
47-AL1/8-ST1A (LA 56)	0,55	0,65

- K', coefficient that depends on the nominal voltage of the line.
    - 0.85, for special category lines.
    - 0.75 for first, second, third category lines.
- F, maximum sag (m).
- L, length of suspension set (m) (tension set L=0).
- D_{PP}, minimum air distance specified.

We will check if this safety distance is met in the most unfavourable case. This happens in the longest span since the sag is larger.

- For the line 1, maximum sag = 3.64 m

It is a span between angle and end of line supports so tension sets will be used (L = 0).

$$D = 0.65 \cdot \sqrt{3.64} + 0.75' \cdot 0.25 = 1.428\ m$$

- For the line 2, maximum sag = 2.27 m

It is a span between an angle supports so, L = 0.

$$D = 0.65 \cdot \sqrt{2.27} + 0.75' \cdot 0.25 = 1.167\ m$$

Once this distance is known we can choose the crossarms.

- Distances to the land, paths and non-navigable water courses.

According to [Section 5.5 of ITC-LAT-07 of RLAT].

The height of the supports will be the necessary so that the distance between the land, path or non-navigable water course and the lowest point of the conductor considering their maximum vertical sag, be at least 6 meters.

- Parallelism between overhead lines.

According to the [section 5.6.2 of ITC-LAT-07 of RLAT].

Whenever possible, its construction will be avoided, at distances less than 1.5 times the height of the highest support.

- Distance to roads

According to [section 5.7.1 of ITC-LAT-07 of RLAT].

The minimum distance of the conductors to the road will be, 7 meters.

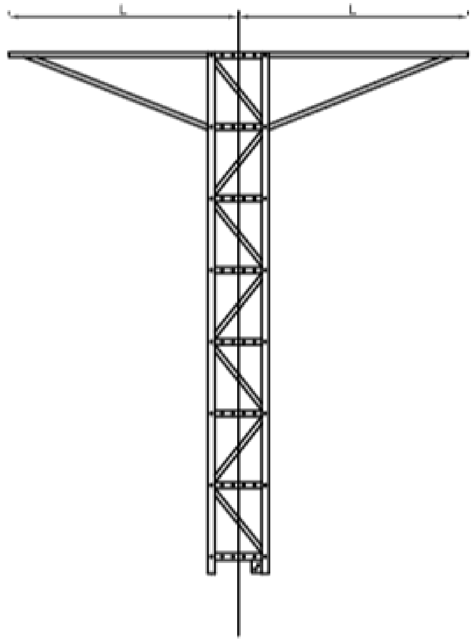
- Distance to buildings

According to [section 5.12.2 of ITC-LAT-07 of RLAT].

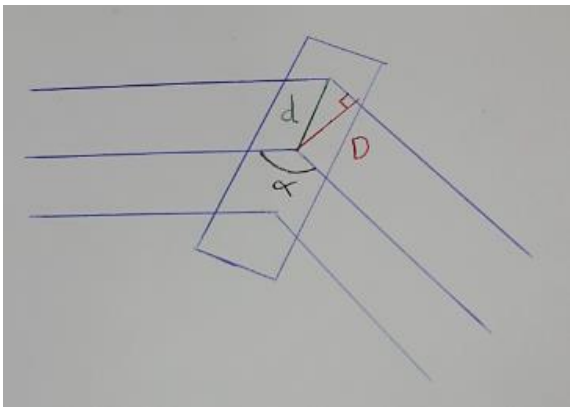
The minimum distance to buildings is 5 meters.

2.1.11 Crossarms

We will use crossarms in horizontal configuration and they will be metallic according to [UNE 207017].



We know that a safety distance between conductors is necessary. Knowing it, we can determine the distance L of the crossarms. We must also bear in mind that in angle supports the distance between conductors will be less than the distance L.



$$\sin\left(\frac{\alpha}{2}\right) = \frac{D}{d}$$

We will calculate the value of d for all angle supports.

$$D = K \cdot \sqrt{F + L} + K' \cdot D_{PP}$$

As we are in Zone A (0-500m) the maximum sag is calculated for the conditions of 15ºC + wind load [section 3.2.3 guide ITC-LAT-07].

The calculation of it will be justified later:

Example for support 2:

$$D = 0.65 \cdot \sqrt{2.27} + 0.75 \cdot 0.25 = 1.167\ m$$

$$L = 0\ (tension\ set)$$

$$d = \frac{D}{\sin\left(\frac{\alpha}{2}\right)} = \frac{1.167}{\sin\left(\frac{145}{2}\right)} = 1.22\ m$$

Support	Max. Sag (m)	Angle	D (m)	d (m)
2	2,27	145	1,167	1,22
4	2,91	173	1,296	1,30
5	2,91	104	1,296	1,65
6	2,27	98	1,167	1,55
7	2,27	142	1,167	1,23
8	2,27	131	1,167	1,28
9	3,64	124	1,428	**1,62**
12	2,27	142	1,167	1,23
13	2,27	121	1,167	**1,34**

Nominal values of L according to the [catalogue of IMEDEXSA], for supports type “C”, are 1m, 1.25m, 1.5m, 1.75m and 2m.

So, for line 1 will be enough to use one of L= 1.75m and for the line 2, L=1.5 m.

2.2 ELECTRICAL CALCULATIONS

2.2.1 Nominal current

The calculation of the nominal current for the network is obtained by solving the following expression:

$$I_n = \frac{S}{\sqrt{3} \cdot U_0}$$

- S = Apparent power kVA
- U_0= nominal voltage

For the line 1:

Total apparent power is the sum of the two middle / low voltage transformers:

$$S_1 = 2 \cdot 400\ kVA = 800\ kVA$$

$$U_0 = 20\ kW$$

$$I_{n1} = \frac{800}{\sqrt{3} \cdot 20} = 23.094\ A$$

For the line 2:

Total apparent power is $S_2 = 400\ kVA$

$$I_{n2} = \frac{400}{\sqrt{3} \cdot 20} = 11.547\ A$$

2.2.2 Maximum admissible current

To calculate the density and maximum admissible permanent regime current, this table will be used. [table 11, section 4.2.1 of guide ITC-LAT 07]

Cross section mm^2	Aluminium current density A/mm^2
15	6
25	5
35	4,55
50	4
70	3,55
95	2,9
125	2,7

As the conductor cross section does not appear in the table, we must interpolate to obtain the value of the current density of the cable that will be used:

$$\frac{70-50}{3.55-4}=\frac{70-54.6}{3.55-\sigma}$$

$$\sigma = 3.8965\ \frac{A}{mm^2}$$

As the conductor is made of aluminium and steel, the interpolation has been made in the aluminium and subsequently according to [section 4.2.1 of guide ITC-LAT 07] a correction factor of 0.937 will be applied for composition of 6 Al+ 1 St wires, getting the density of the conductor:

$$\sigma' = \sigma \cdot 0.937 = 3.651\ \frac{A}{mm^2}$$

The maximum admissible current in permanent regime for alternating current and frequency of 50 Hz is:

$$I_{adm} = \sigma' \cdot S = 3.651 \cdot 54.6 = 199.35\ A$$

That is greater than the nominal current to be transported in our network.

2.2.3 Resistance

The tests carried out by the manufacturer on the LA-56 tell us that its ohmic resistance per kilometre for 20 ºC has a value:

$$R_{20} = 0.6129\ \frac{\Omega}{Km}$$

The electrical resistance of the conductor varies according to its temperature. Therefore, for calculation purposes, the resistance value at 75ºC will be used, considered as the ambient temperature plus the temperature acquired by the conductor due to the passage of the current.

To calculate this value, the following expression will be used:

$$R_{75} = R_{20} \cdot [1 + \alpha \cdot (T - 20)]$$

- α, coefficient of variation of resistivity for aluminium= 0.0037 ºC^{-1}

$$R_{75} = R_L = 0.6129 \cdot [1 + 0.0037 \cdot (75 - 20)] = 0.7376\ \frac{\Omega}{Km}$$

The length of the line 1 is L_1=1.145 Km.

So the total resistance for the main line is:

$$R_1 = R_L \cdot L_1 = 0.7376 \cdot 1.145 = 0.8445\ \Omega$$

The length of the line 2 is L_2=0.360 Km.

So the total resistance for the line 2 is:

$$R_2 = R_L \cdot L_2 = 0.7376 \cdot 0.360 = 0.2655\ \Omega$$

2.2.4 Reactance

The inductance of the line produces an inductive reactance in series with resistance:

$$X_L = w \cdot L_L \cdot L = 2 \cdot \Pi \cdot f \cdot L_L \cdot L$$

Where:

- f, frequency = 50Hz
- L_L, inductance per length unit, H/km

$$L_L = 2 \cdot 10^{-4} \cdot Ln \frac{DMG}{RMG'}$$

- L, line length, km
    - DMG, is the geometric mean distance between the phases.

For lines with one conductor per phase:

$$DMG = \sqrt[3]{d_{12} \cdot d_{23} \cdot d_{31}}$$

Where:

- d_{12}, d_{23}, d_{31}=Distance between the different conductors, in mm.

In our case, for line 1.

- $d_{12} = 1750\,mm$
- $d_{23} = 1750\,mm$
- $d_{31} = 3500\,mm$

$$DMG1 = \sqrt[3]{1750 \cdot 1750 \cdot 3500} = 2204.86\,mm$$

For line 2,

- $d_{12} = 1500\,mm$
- $d_{23} = 1500\,mm$
- $d_{31} = 3000\,mm$

$$DMG1 = \sqrt[3]{1500 \cdot 1500 * 3000} = 1889.88\,mm$$

- RMG' = geometric mean radius. Equivalent radius of an empty circular conductor to calculation effects of the induction coefficients, in mm.

$$RMG' = e^{-\frac{1}{4}} \cdot r$$

Where:

- r, conductor radius, in mm =4.725 mm

$$RMG' = e^{-\frac{1}{4}} \cdot 4.725 = 3.68\,mm$$

For what we get:

For line 1:

$$L_{L1} = 2 \cdot 10^{-4} \cdot Ln\frac{2204.86}{3.68} = 0.00128\,\frac{H}{km}$$

For line 2:

$$L_{L2} = 2 \cdot 10^{-4} \cdot Ln\frac{1889.88}{3.68} = 0.00125\,\frac{H}{km}$$

The reactance per length unit, for line 1:

$$X_{L1} = 2 \cdot \Pi \cdot 50 \cdot 0.00128 = 0.402\,\frac{\Omega}{km}$$

For line 2:

$$X_{L1} = 2 \cdot \Pi \cdot 50 \cdot 0.00125 = 0.3927\,\frac{\Omega}{km}$$

The reactance for the line 1 is:

$$X_1 = 0.402 \cdot 1.145 = 0.46\,\Omega$$

The total reactance for the line 2 is:

$$X_2 = 0.393 \cdot 0.360 = 0.142\,\Omega$$

2.2.5 Voltage drops

The voltage drop produced at any point of the line can be calculated with the following formula.

$$\Delta U = \sqrt{3} \cdot I \cdot L \cdot (R_L \cdot Cos\varphi + X_L \cdot sen\varphi)$$

- I, nominal current (A)
- L, length (km)
- R_L, ohmic resistance (Ω/km)
- X_L, reactance (Ω/km)

And expressed in percentage:

$$\Delta U_{\%} = \frac{P \cdot L}{10 \cdot U^2}(R_L + X_L \cdot tg\varphi)$$

Where:

- P, active power (W)
- U, nominal voltage (V)
- L, length of the line (km)
- R_L, ohmic resistance (Ω/km)
- X_L, reactance (Ω/km)
- $tg\varphi$, tangent of the phase angle.

We will calculate the voltage drop of the line expressed in percentage, knowing that it must be less than 7%.

We calculate the voltage drop in line 1.

The voltage drop to the transformation centre 1.

$$\Delta U_{TC1} = \sqrt{3} \cdot 23.094 \ \cdot 0.51 \cdot (0.7376 \cdot 0.9 + 0.402 \cdot 0.4359) = 17.117\,V$$

$$\Delta U_{TC1\%} = \frac{720 \cdot 0.51}{10 \cdot 20^2}(0.7376 + 0.402 \cdot 0.4843) = 0.0855\%$$

We consider that the voltage is the same as at the beginning of the line since the voltage drop produced up to this point is insignificant.

After feeding the transformation centre TC1 the current that remains is:

$$I_3 = \frac{400}{\sqrt{3} \cdot 20} = 11.547\ A$$

The voltage drop produced between the transformation centre TC1 and transformation centre TC2 is:

$$\Delta U_{TC2} = \sqrt{3} \cdot 11.547\ \cdot 0.635 \cdot (0.7376 \cdot 0.9 + 0.402 \cdot 0.4359) = 10.656\ V$$

$$\Delta U_{TC2\%} = \frac{360 \cdot 0.635}{10 \cdot 20^2}(0.7376 + 0.402 \cdot 0.4843) = 0.053\%$$

Therefore the voltage drop from the start of the line 1 is:

$$\Delta U_1 = \Delta U_{TC1} + \Delta U_{TC2} = 17.117 + 10.65 = 27.767\ V$$

$$\Delta U_{\%1} = \Delta U_{\%TC1} + \Delta U_{\%TC2} = 0.0855 + 0.053 = 0.1385\ \% \ < 7\%$$

The voltage drop produced in the line 2 is:

$$\Delta U_2 = \sqrt{3} \cdot 11.547\ \cdot 0.36 \cdot (0.7376 \cdot 0.9 + 0.3927 \cdot 0.4359) = 6.012\ V$$

$$\Delta U_{2\%} = \frac{360 \cdot 0.36}{10 \cdot 20^2}(0.7376 + 0.3927 \cdot 0.4843) = 0.03\% < 7\%$$

2.2.6 Maximum admissible power

$$P_{adm} = \sqrt{3} \cdot U \cdot I_{adm} \cdot cos\varphi$$

$$P_{adm} = \sqrt{3} \cdot 20000 \cdot 199.35\ \cdot 0.9 = 6215.12\ kW$$

Maximum power that we will transport in line 1:

$$P_{max1} = \sqrt{3} \cdot 20000 \cdot 23.09\ \cdot 0.9 = 719.87\ kW$$

In line 2:

$$P_{max1} = \sqrt{3} \cdot 20000 \cdot 11.547\ \cdot 0.9 = 359.99\ kW$$

The value obtained from the maximum admissible power that can be transported by the conductor is greater than the value of the maximum power that is transported in the line.

2.2.7 Short-circuit currents

The losses caused by the Joule effect on conductors due to a short circuit, raise its temperature to values dependent on the intensity and duration of the fault, which can cause a decrease in the operational characteristics of them.

The limit temperature that an aluminium-steel conductor can reach, without causing a decrease in its characteristics should not exceed 200 ºC.

$$I_{cc} = \frac{K}{\sqrt{t}}$$

- t, duration of the fault
- k, admissible short circuit current for 1 second.

$$K = \sqrt{10^{-3} \cdot \frac{S \cdot C}{\alpha \cdot R_{20}} \cdot \ln\left(\frac{1 + \alpha \cdot (\theta_2 - 20)}{1 + \alpha \cdot (\theta_1 - 20)}\right)} = 4.51\ kA$$

  - S, conductor cross section
  - C, specific heat of the conductor per unit volume = 2.6 J/cm^{3}ºC
  - α, coefficient of variation of resistivity for aluminium= 0.0037 ºC^{-1}
  - R_{20}, ohmic resistance 20ºC (Ω/km)
  - θ_2, final temperature after the fault = 200ºC
  - θ_1, operational temperature = 75ºC

Short circuit duration (s)	0,1	0,2	0,3	0,4	0,6	0,8	1	2	3	5
Admissible short circuit current (kA)	14,58	10,31	8,42	7,29	5,95	5,15	4,61	3,26	2,66	2,02

To protect our line against short circuits we use the fuse, design by [BUSSMAN] company:

- For line 1:

Type	Voltage rating	Nominal curren	Breaking capacity	Minimum breaking current	Weight
	Un (kV)	In (A)	I1 (kA)	I3 (A)	(kg)
24FDMSJ25	24	25	35.4	25	2,2

As we can check, the breaking capacity is greater than the admissible short-circuit current at 0.1s for the LA 56 conductor.

$$I_{scmax\ (t=0.1s)} = 14.58\ kA$$

Checking the i-t characteristics we can see that for a time of 0.1 seconds, I_f= 260 A.

$$I_{f(0.1)} < I_{scmax}$$

- For line 2:

Type	Voltage rating	Nominsl current	Breaking capacity	Minimum breaking current	Weight
	Un (kV)	In (A)	I1 (kA)	I3 (A)	(kg)
24SFMSJ16	24	16	35.5	16	2,2

Checking the i-t characteristics we can see that for a time of 0.1 seconds, I_f= 160 A.

Therefore, the lines will be protected.

2.2.8 Disconnectors

To perform operations on the line we will install unipolar disconnectors at the beginning of the lines.

Its characteristics are provided by the manufacturer [INAEL].

Type	Un (kV)	Ith (kA)	In (A)	Creepage distance (mm)	Ultimate strength (N)	Weight (kg)
SU 1,110	24	16	400	625	3000	18

2.2.9 Lightning arrester

To avoid overvoltages we use lightning arrester, whose characteristics are provided by the manufacturer [SIEMENS].

Reference	Assigned voltage	Maximum operating voltage of the line	Normalized withstand voltage to lightning impulses	Weight
3EKT 300 4CF4	Ur (Kv)	Uc (kV)	(kV)	(kg)
	30	24	160	2.9

2.3 MECHANICAL CALCULATIONS

2.3.1 Mechanical calculation of conductors

First thing we have to take into account is that we must meet the following conditions according to the article [3.2 of ITC-LAT 07]:

- The safety factor at failure, is at least equal to 3 in the atmospheric conditions that cause maximum tension of the conductors.
- The working tension of the conductors at 15^0 C without any overload, does not exceed 15% of the failure load.
- The working tension of the conductor at -5^0 C without any overload, does not exceed 20% of the failure load.

2.3.1.1 CONDUCTORS MAXIMUM TENSIONS

As we are in zone A, the maximum tension appears in the conditions of -5^0 C and wind blowing.

Under these conditions we will calculate the maximum tensions according to each span.

The maximum tension will not be greater than their ultimate strength divided by 3.

2.3.1.2 RULING SPAN

Fictitious single span in which tension variations due to load or temperature changes are nearly the same.

The spans that are between support equipped with tension sets for the purpose of calculating tensions in the conductor can be considered as one, because the tension in each span is the same, whose length will be:

$$a_r = \sqrt{\frac{\sum a_n{}^3}{\sum a_n}}$$

- a_n, length of each span between tension sets.

In our case we have a span of this type between supports 2-4.

$$a_{r2-4} = \sqrt{\frac{120^3 + 132.5^3}{120 + 132.5}} = 126.71\ m$$

2.3.1.3 CONDUCTOR'S WEIGHT DUE TO WIND LOAD

In order to calculate the weight of the conductor we must take into account the following: [section 3.1.2 guide ITC-LAT 07]

- The line is installed in an area less than 500m above sea level, so it is in Zone A. So the wind pressure will be 120 km / h (60 daN / m2 for conductors with a cross section less than 16mm^2).

To calculate the weight of the conductor with wind overload, the following will apply expressions:

$$W_w = p_w \cdot d$$

$$W_T = \sqrt{{W_w}^2 + {W_{LA-56}}^2}$$

Where:

- W_w, Wind load (daN /m)
- p_w, Wind pressure (daN / m2)
- d, conductor diameter (m)
- W_{LA-56} , characteristic weight of the conductor (daN/m)
- W_T, total weight of the conductor with wind load (daN/m)

$$W_w = 60 \cdot 9.45 \cdot 10^{-3} = 0.567\ daN/m$$

$$W_T = \sqrt{0.567^2 + 0.185^2} = 0.596\ daN/m$$

2.3.1.4 EVERY DAY STRESS (EDS)

Vibratory factor whose meaning refers to the tension that a cable is subjected most of the time corresponding to the average temperature, or temperatures close to it, and considering the cable without overload.

In Spain, the average temperature is 15ºC. [section 3.2.2 guide ITC-LAT-07].

$$EDS\ (\%) = \frac{T_{15ºC}}{T_{ultimate\ strength}} \cdot 100 \leq 15\%$$

2.3.1.5 COULD HOUR STRESS (CHS)

In Spain, it is usually considered, as average temperature, -5ºC. [section 3.2.2 guide ITC-LAT-07]

$$CHS\ (\%) = \frac{T_{-5ºC}}{T_{ultimate\ strength}} \cdot 100 \leq 20\%$$

According to the tables of mechanical calculation of the conductor attached in an annex we can know if our conductor meets the conditions previously described:

As we mentioned before the ultimate strength is 1629 daN.

For span 1-2:

- Length 120 m.
- $Max.tension = 543\ daN$

$$Safety\ factor = \frac{Ultimate\ strength}{Max.tension} = \frac{1629}{543} \leq 3$$

- Tension (15 ºC) = 229 daN

$$EDS = \frac{\text{Tension (15 ºC)}}{Ultimate\ strength} \cdot 100 = \frac{229}{1629} \cdot 100 = 14.06\ \% \leq 15\%$$

- Tension (-5ºC) = 316 daN

$$CHS = \frac{\text{Tension } (-5\text{ ºC})}{Ultimate\ strength} \cdot 100 = \frac{316}{1629} \cdot 100 = 19.4\% \leq 20\%$$

Span	Length (m)	Max. Tension (daN)	Safety factor (=>3)	Tension (daN)(15ºC)	EDS <= 15%	Tension (daN) (-5ºC)	CHS <= 20%
1-2	120	543	3	229	14,06	316	19,40
2-4	126,71	543	3	223,63	13,73	300,57	18,45
4-5	137,5	543	3	215	13,20	279,5	17,16
5-6	120	543	3	229	14,06	316	19,40
6-7	120	543	3	229	14,06	316	19,40
7-8	120	543	3	229	14,06	316	19,40
8-9	120	543	3	229	14,06	316	19,40
9-10	155	543	3	204,5	12,55	251,5	15,44

11-12	120	543	3	229	14,06	316	19,40
12-13	120	543	3	229	14,06	316	19,40
13-14	120	543	3	229	14,06	316	19,40

As we can see in the table the conditions are met.

2.3.1.6 MAXIMUM SAG

As the line is in zone A the maximum sag is produced for the conditions of 15 ºC with wind load or for 50 º C. [section 3.2.3 guide ITC-LAT-07].

Looking at the tables of mechanical calculation we can see that for the lengths of span that we have the maximum sag is produced for the first condition.

Span	Length (m)	Max. sag (m) (15ºC + wind)	Max. Sag (m) (50ºC)
1-2	120	2,27	2,18
2-3	120	2,27	2,18
3-4	132,5	2,71	2,62
4-5	137,5	2,91	2,81
5-6	120	2,27	2,18
6-7	120	2,27	2,18
7-8	120	2,27	2,18
8-9	120	2,27	2,18
9-10	155	3,64	3,52
11-12	120	2,27	2,18
12-13	120	2,27	2,18
13-14	120	2,27	2,18

The maximum sag is produced for the span 9-10. This span crosses a road, whose minimum safety distance to the conductors of the line is 7 meters. Therefore, taking into account the nominal heights of the supports and their foundations. We must choose supports of 14 meters of height for the line 1. [Imedexsa manufacturer catalogue].

For supports of 14 meters, the minimum height from the highest point of the support to ground taking into account the foundations is 11.59m.

Therefore, the minimum distance to ground considering the maximum sag is 7.95 meters.

As the sags are smaller for line 2 we can install supports of 12 meters nominal height for this line.

For supports of 12 meters, the minimum height from the highest point of the support to ground taking into account the foundations is 9.61 meters.

Therefore, the minimum distance to ground considering the maximum sag is 7.34 meters.

2.3.2 Mechanical calculation of supports

We will use lattice structure supports made of galvanized metal type "C" according to [UNE 207017].

The nominal effort values are C-500, C-1000, C-2000, C-3000, C-4500, C-7000, C-9000.

[Imedexsa catalogue]

To analyse the efforts on the supports, the calculation indications in the [section 3.5.3 of ITC-LAT 07 of the R.L.A.T.] will be taken into account.

Should be taken into account, depending on the type of support and the area in which it is located, the following hypotheses:

- 1st hypotheses, wind.
- 2nd hypotheses, ice.
- 3rd hypotheses, imbalance of tensions.
- 4th hypotheses, conductors breaking.

As we are in zone A the 2nd hypothesis is rejected.

According to the [section 3.5.3 of ITC-LAT07], in lines of 2nd and 3rd category using conductors with ultimate strength less than 6600 daN, the consideration of the 4th hypothesis can be omitted, when the following conditions are verified:

- Conductors have a safety factor of at least 3.
- The safety coefficient of the supports in the third hypothesis is that corresponding to the normal hypotheses.
- Install supports using tension sets every 3 km maximum.

Next we will show the corresponding equations for each hypothesis of calculation and for each type of support [section 3.5.3 of ITC-LAT07].

Each support equipped with suspension set, use three of them.

Each support equipped with tension set, use six of them, except end and start of line supports which use three.

2.3.2.1 INTERMEDIATE SUPPORT (SUSPENSION SET)

LOAD	1st hypotheses	3td hypotheses	4th hypotheses
V (vertical)	$W_{cond} + W_{eq} + W_{cross}$	$W_{cond} + W_{eq} + W_{cross}$	$W_{cond} + W_{eq} + W_{cross}$
T (transverse)	$n \cdot F_T$	0	0
L (longitudinal)	0	$n \cdot (\%\, imb) \cdot T_w$	$(\%\, bre) T_w$

- n, number of conductors.
- T_w, conductor horizontal tension (-5ºC, wind 120 km/h)
- $W_{cond} = n \cdot W_{LA-56} \cdot \left[\frac{a_1+a_2}{2}\right]$
- $F_T = p_w \cdot \left[\frac{a_1+a_2}{2}\right]$
- % imb = imbalance coefficient for intermediate supports. If $U_n \leq 66\ kV$ % imb=0.08.
- W_{cross}, crossarms weight.
- $W_{equipment\ (1^{st} support\ of\ line)} = W_{sets} + W_{disconnectors} + W_{lightning\ arresters} + W_{fuses}$
- $W_{equipment\ (rest\ of\ suppport)} = W_{sets}$

2.3.2.2 INTERMEDIATE SUPPORT (TENSION SET)

LOAD	1st hypotheses	3rd hypotheses	4th hypotheses
V (vertical)	$W_{cond} + W_{eq} + W_{cross}$	$W_{cond} + W_{eq} + W_{cross}$	$W_{cond} + W_{eq} + W_{cross}$
T (transverse)	$n \cdot F_T$	0	0
L (longitudinal)	0	$n \cdot (\%\ imb) \cdot T_w$	$n \cdot (\%\ bre) T_w$

- n, number of conductors.
- $F_T = p_w \cdot \left[\frac{a_1+a_2}{2}\right]$
- T_w, bigger conductor horizontal tension of the bordering spans (-5ºC, wind 120 km/h)
- % imb = imbalance coefficient for intermediate supports. If $U_n \leq 66\ kV$ % imb=0.5

2.3.2.3 ANGLE SUPPORT

LOAD	1st hypotheses	3rd hypotheses	4th hypotheses
V (vertical)	$W_{cond} + W_{eq} + W_{cross}$	$W_{cond} + W_{eq} + W_{cross}$	$W_{cond} + W_{eq} + W_{cross}$
T (transverse)	[1]	$n \cdot (2 - \%\ imb) \cdot T_{w1} \cdot sin\left(\frac{\alpha}{2}\right)$	$[n \cdot T_{w1} + (n-1) \cdot T_{w2}] \cdot\ sin\left(\frac{\alpha}{2}\right)$
L (longitudinal)	0	$n \cdot (\%\ imb) \cdot T_{w1} \cdot cos\left(\frac{\alpha}{2}\right)$	$[n \cdot T_{w1} - (n-1) \cdot T_{w2}] \cdot\ cos\left(\frac{\alpha}{2}\right)$

$$[1] \quad n \cdot (T_{w1} + T_{w2}) \cdot sin\left(\frac{\alpha}{2}\right) + n \cdot \frac{a_1 + a_2}{2} \cdot p_w \cdot cos^2\left(\frac{\alpha}{2}\right)$$

- n, number of conductors.
- % imb = imbalance coefficient for intermediate supports. If $U_n \leq 66\ kV$ % imb=0.15
- T_{w1},previous span conductor horizontal tension (-5ºC, wind 120 km/h).
- T_{w2},following span conductor horizontal tension (-5ºC, wind 120 km/h).
- α, deviation angle.

2.3.2.4 START AND END OF LINE SUPPORTS

LOAD	1ª hypotheses	3ª hypotheses	4ª hypotheses
V (vertical)	$W_{cond} + W_{eq} + W_{cross}$	No	$W_{cond} + W_{eq} + W_{cross}$
T (transverse)	$n \cdot F_T$	No	0
L (longitudinal)	$n \cdot T_w$	No	$n \cdot T_w$

- $W_{cond} = n \cdot W_{LA-56} \cdot \left[\frac{a}{2}\right]$
- n, number of conductors.
- $F_T = p_w \cdot \left[\frac{a}{2}\right]$
- T_w, conductor horizontal tension (-5ºC, wind 120 km/h)

Data for calculations:

- n=3
- $W_{LA-56} = 0.185\ daN/m$
- $W_{cross}(line\ 1) = 45.08\ daN$
- $W_{cross}(line\ 2) = 41.16\ daN$
- $W_{set}\ (tension) = 8.61\ daN$
- $W_{set}\ (suspension) = 9.59\ daN$
- $W_{disconnector} = 17.64\ daN$
- $W_{lightning\ arresters} = 2.84\ daN$
- $W_{fuses} = 2.16\ daN$
- $T_w = 543\ daN$
- $p_w = 0.567\ daN/m$

Example of calculation support number 3 (Intermediate, suspension)

- a_1= 120 m.
- a_2=132.5 m.

- 1st hypotheses

Vertical load

$$V_L = W_{cond} + W_{eq} + W_{cross}$$

$$W_{cond} = n \cdot W_{LA-56} \cdot \left[\frac{a_1 + a_2}{2}\right] = 3 \cdot 0.185 \cdot \left[\frac{120 + 132.5}{2}\right] = 70.07\ daN$$

$$W_{eq} = W_{set} = 3 \cdot 9.59 = 28.77\ daN$$

$$W_{cross} = 45.08\ daN$$

$$V_L = 70.07 + 28.77 + 45.08 = 143.92\ daN$$

Transverse load

$$T_L = n \cdot F_T$$

$$F_T = p_w \cdot \left[\frac{a_1 + a_2}{2}\right] = 0.567 \cdot \left[\frac{120 + 132.5}{2}\right] = 71.58\ daN$$

$$T_L = 3 \cdot 71.58 = 214.75\ daN$$

- 3rd hypotheses

Vertical load is the same as 1st hypotheses.

Longitudinal load

$$L_L = n \cdot (\%\ imb) \cdot T_w$$

- $\%\ imb = 0.08$

- $T_w = 543\ daN$

$$L_L = 3 \cdot 0.08 \cdot 543 = 130.32\ daN$$

Example of calculation support number 2 (Angle)

- a_1= 120 m.
- a_2= 120 m.
- α= 35^O
- $\%\ imb = 0.15$

- 1st hypotheses

Vertical load

$$V_L = W_{cond} + W_{eq} + W_{cross}$$

$$W_{cond} = n \cdot W_{LA-56} \cdot \left[\frac{a_1 + a_2}{2}\right] = 3 \cdot 0.185 \cdot \left[\frac{120 + 120}{2}\right] = 66.6\ daN$$

$$W_{eq} = W_{set} = 6 \cdot 8.61 = 51.66\ daN$$

$$W_{cross} = 45.08\ daN$$

$$V_L = 66.6 + 51.66 + 45.08 = 163.34\ daN$$

Transverse load

$$F_T = n \cdot (T_{w1} + T_{w2}) \cdot sin\left(\frac{\alpha}{2}\right) + n \cdot \frac{a_1 + a_2}{2} \cdot p_w \cdot cos^2\left(\frac{\alpha}{2}\right)$$

$$F_T = 3 \cdot (543 + 543) \cdot sin\left(\frac{35}{2}\right) + 3 \cdot \frac{120 + 120}{2} \cdot 0.567 \cdot cos^2\left(\frac{35}{2}\right) = 1165.36\ daN$$

- 3rd hypotheses

Vertical load is the same as 1st hypotheses.

Transverse load

$$F_T = n \cdot (2 - \%\, imb) \cdot T_{w1} \cdot sin\left(\frac{\alpha}{2}\right)$$

$$F_T = 3 \cdot (2 - 0.15) \cdot 543 \cdot sin\left(\frac{35}{2}\right) = 906.22\ daN$$

Longitudinal load

$$F_L = n \cdot (\%\, imb) \cdot T_{w1} \cdot cos\left(\frac{\alpha}{2}\right)$$

$$F_L = 3 \cdot 0.15 \cdot 543 \cdot cos\left(\frac{35}{2}\right) = 233.04\ daN$$

Example of calculation support number 1 (Start of line)

- a=120 m.
- 1^{st} hypotheses

Vertical load

$$V_L = W_{cond} + W_{eq} + W_{cross}$$

$$W_{cond} = n \cdot W_{LA-56} \cdot \left[\frac{a}{2}\right] = 3 \cdot 0.185 \cdot \left[\frac{120}{2}\right] = 33.32\ daN$$

$$W_{eq} = W_{sets} + W_{disconnectors} + W_{lightning\ arresters} + W_{fuses}$$

$$W_{eq} = 3 \cdot 8.61 + 3 \cdot 17.64 + 3 \cdot 2.84 + 3 \cdot 2.16 = 93.74\ daN$$

$$W_{cross} = 45.08\ daN$$

$$V_L = 33.3 + 93.74 + 45.08 = 172.14\ daN$$

Transverse load

$$T_L = n \cdot F_T = 3 \cdot 0.567 \cdot \left[\frac{120}{2}\right] = 102.06\ daN$$

Longitudinal load

$$L_L = n \cdot F_T = 3 \cdot 543 = 1629\ daN$$

Support		Previous span length (m)	Following span length (m)	Angle	1ª Hypotheses (daN)			3ª Hypotheses (daN)			Support
Nº	Type				V	T	L	V	T	L	
1	Start of line		120		172,14	102,06	1629	0	0	0	C-2000
2	Angle	120	120	145	163,37	1165,36	0	163,37	906,22	233,04	C-2000
3	Intermediate (sus)	120	132,5		143,92	214,75	0	143,92	0	130,32	C-500
4	Angle	132,5	137,5	173	171,69	3674,64	0	171,69	183,98	243,89	C-4500
5	Angle	137,5	120	104	168,22	4305,78	0	168,22	1855,39	192,55	C-4500
6	Angle	120	120	98	163,37	2137,44	0	163,37	1977,13	184,41	C-3000
7	Angle	120	120	142	163,37	1060,70	0	163,37	981,15	231,04	C-2000
8	Angle	120	120	131	163,37	1351,07	0	163,37	1249,74	222,35	C-2000
9	Angle	120	155	124	173,08	1529,54	0	173,08	1414,82	215,75	C-2000
10	End of line	155			113,94	131,83	1629	0	0	0	C-2000
11	Start of line		120		168,22	102,06	1629	0	0	0	C-2000
12	Angle	120	120	142	159,45	1060,70	0	159,45	981,15	231,04	C-2000
13	Angle	120	120	121	159,45	1604,32	0	159,45	1483,99	212,67	C-2000
14	End of line	120			100,3	102,06	1629	0	0	0	C-2000

3. MICROGRID

3.1 INTRODUCTION

3.1.1 State of art

Nowadays, more than 1400 million people (about 20% of the world population) lack electricity supply. Another 3 billion (40% of the global population) use biomass (firewood, food waste, agricultural waste ...) to satisfy basic needs, such as cooking and heating. What is called "energy poverty". The use of this type of energy source generates air pollution in open and closed spaces, a problem that causes around 4.3 million deaths every year. At this rate, the world will only reach 92% of electrification by 2030, which means that many people will not have access to electricity and will not be able to take advantage of the social and economic opportunities that can help them improve their lives. [1]

These data show the importance of energy in satisfying the basic needs of the population. So, the commitment of science and technology to face this problem is imminent, optimizing existing resources for any person to have an adequate quality of life.

Considering the conditions presented, it is vital to argue that any global energy solution must consider an electricity supply, which will supply most of the energy needs. Therefore, take electric power to the isolated areas, that is, areas not connected to the grid, which remain still lacking in electricity supply; presents a great challenge and an opportunity to improve the systems and technologies involved for this purpose.

When electricity was introduced for the first time in the cities, the industrialized countries tended to centralized electricity generation, that is, large power plants far from consumption points. The first plants developed were hydraulic power stations and later thermal power plants (nuclear or conventional). These large facilities were a good example of economy of scale, where investment is optimized, and expenses are reduced.

The centralized generation is also characterized by a meshed and radial configuration of the transport system and the distribution system; and a unidirectional energy flow, from the generator to the consumer.

The problem of this type of generation and distribution lies in its low efficiency, since it requires large routes of electricity, from where it is generated to its final consumption, with consequent transport losses. The second major problem is the operational difficulty due to the great variability of demand throughout the day and year.

This described model has remained stable for a long time, but new politics of sustainable development and regulatory changes, adding to this the current price of oil, advocate the expansion renewable energies. Likewise, advances in generation technologies have meant that the minimum cost, per unit of power generated, is obtained in plants of smaller size and power generated. This fact, added to the high level of efficiency achieved in smaller power plants, the availability of renewable energy generation technology and the release of the electricity market have promoted the transition to a distributed electricity generation system. This model consists of small generation facilities generally connected to the distribution grid and covering any small-scale technology that provides electricity at points close to the consumer.

The transition from a centralized electrical system to a distributed electrical system is a trend that involves the reduction of the environmental impact associated with centralized electricity production based on fossil fuels, the reduction of greenhouse gas emissions, the integration of the use of resources renewable energies and the improvement of the efficiency of the electrical system, reducing transport losses.

To capitalize on the advantages of distributed generation, it has evolved to the concept of microgrids, this aspect of distributed generation has been found as the most appropriate for the type of isolated areas, given its flexibility to adapt to these areas, and the management capabilities generation and demand, which is expected to play an important role in electricity generation systems soon.

Developing microgrids oriented to provide energy to isolated populations of the public electricity grid, involves a series of particularities that make it differ from conventional energy supply grids, such as its control and operation strategies, in which the relationship between demand and the sources of generation that operate in an instant are much narrower than in the case of a conventional system.

3.1.2 Definition

A microgrid has been conceptualized as an integrated electrical network, which uses distributed energy sources (mostly renewable) and, generally, energy storage devices to supply the demand. [2]

It normally uses electricity generation from wind turbines, photovoltaic modules and diesel backup. The use of photovoltaics as a generating source in microgrids is the most common, its use being widespread with a wide difference compared to other sources. We could say that it is the energy base on which the other sources pivot and complement each other.

The combination of renewable energy sources with a battery energy storage system that can resolve consumption peaks, renewable production transients and the low night consumption, which in most cases are required, has proven to be a low-cost reliable solution for isolated communities. If in addition, to this system we attach a back-up generating equipment whose main mission is as an emergency before the natural fluctuations of renewable resources (whether seasonal or specific) or to adapt to unexpected changes in consumption profiles, we are facing a generator system absolutely valid and reliable, which also does not depend too much on the problems and increasing costs of fossil fuels.

The microgrid is part of a broader concept that has been called "smart grid" and has as a background the electrical installations where the loss of energy would be catastrophic (hospitals, shopping centers, data centers, etc.). When the supply of the main network in these facilities is lost, generation is based on gas or diesel turbines. The main difference with the concept of microgrid is that it has the capacity, through communication and computing technologies, to operate autonomously, either in isolation or in coordination with the network of the supplying company, as well as the possibility of selling its surpluses. of energy to the supplier company. [2]

3.1.3 Operation ways

Regarding the operating modes, the microgrid can operate interconnected to the general electrical grid, through one or several PCC (Point of Common Coupling) or it can operate in an isolated way, as will be our case. The operational requirements in each case are different and the control and stability specifications also diverge. [3]

- Connected to the grid: the microgrid tries to supply the largest amount of demand, manage the charge / discharge of the storage systems, so that the grid functions as a balance node, absorbing or delivering the differences of energy. In addition, the connection point provides a voltage and frequency reference that helps maintain these parameters also in the microgrid.

  In this situation it is not necessary that all the energy demanded by the loads be produced by the generators of the microgrid since the difference between generation and consumption will be covered by the energy that flows through the connection point. The microgrid can be seen as a small generator or as a load depending on whether the generation is greater or less than the energy demanded by the loads. When the micro grid works connected to the distribution network, the control system aims to reduce the cost of energy for the consumers that are associated with it. Use local generation when it is economically profitable, decreasing the amount of energy it takes from the grid.

- Disconnected from the grid: operating in an isolated and autonomous way has a favourable effect on the quality and reliability of the electricity supply.

  Microgrids that are isolated from the grid must continuously look for the balance between generation and demand, therefore the information acquisition systems are very important for an optimal operation.

Traditionally, isolated electrical systems have been served by in situ generation, based on available resources or easily transportable and storage fuels, mainly hydrocarbons. The great advantage of renewable sources is the use of energies such as the sun, wind or water resources that can be locally abundant and become viable options for places where it is very difficult to transport fuels. In this environment, microgrids are an alternative to efficiently manage the generation and control the process of charging and discharging the storages.

The sources must be sized to supply the load and an adequate safety margin. The control systems, therefore, seek to maintain voltage and frequency levels with few deviations from the reference points.

3.1.4 Advantages

The main advantages are: [4]

- *Improvement in the quality of supply*: the technology involved in the management and operation offers multiple factors that guarantee a substantial improvement in the quality and stability of the supply. Some of them are the decentralization and the fragmentation of supply, the smallest discrepancy between generation and consumption or the mitigation of the effects produced by transport lines.

- *Operational improvement:* the physical approach between generation sources and consumption contributes to a reduction in transportation and distribution losses. The fragmentation provided by microgrids guarantees a reduction in investments related to the expansion of the electrical system.

- *Increase in efficiency and economic savings:* the proximity between generation and consumption allows the development of processes from which to take advantage of "useless heat", increasing efficiency up to values close to 80% compared to 40% of conventional systems. This strong increase in efficiency linked to the decrease in investment in transport and distribution leads to a significant and significant reduction in costs.

- *Decrease in environmental impact:* the development, management and operation of the microgrids is associated with a reduction in the environmental impact compared to the conventional system. The reduction of combustion processes and their greater control directly implies a decrease in emissions helping to combat global warming. All this is reinforced by the users' concern in making responsible use of energy, since there is a physical proximity between generation sources and customers.

- *They can operate both connected to the public distribution network and isolated from it*. The public network would also benefit from these microgrids, since they would support their operation in case of failure.

- *Even consumers who do not enjoy the direct benefits of microgrids can also benefit from these systems.* It is because an increase in the use of these will mean a reduction of energy costs due to the reduction of the peak demand in the distribution network.

3.1.5 Disadvantages

The main disadvantages are: [4]

- *Lack of regulation:* the incipient development of the microgrids supposes an area too unexplored, for which reason there is no strict regulation. It is necessary to join efforts for the creation of a standard that establishes protocols to which to govern.

- *Legal impediments:* the insertion of new sources of generation and the transformation of the traditional electric system, is a framework in which future governments should emphasize, since many are the countries in which there is a legal vacuum or even legal barriers imposed by the electric monopoly.

- *High cost*: the main drawback of the installation of microgrids is their high current cost. A problem that can be mitigated by the commitments made by the EU in terms of reducing CO2 emissions, which could be considered as a period of transition.

- *Technical difficulties*: the lack of technical experience in controlling many generation sources is a weak point. A telecommunications infrastructure must be developed that allows the development of aspects such as control or protection.

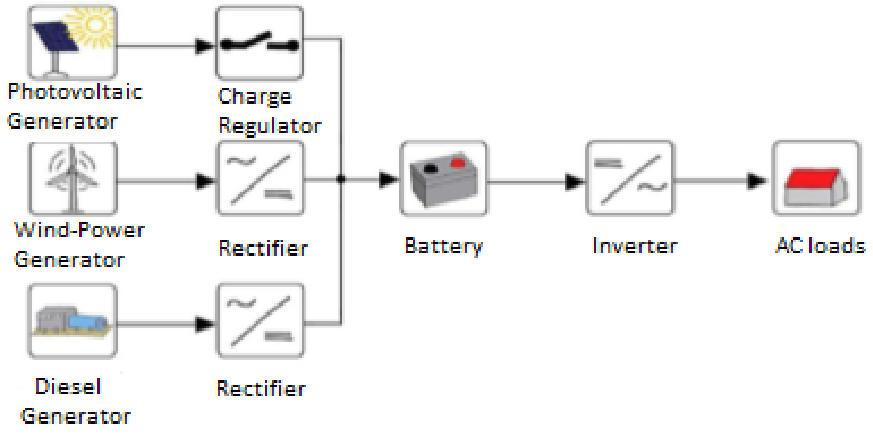
- *Dependence on the weather*: therefore, there will be days when there is excess production, and others when the generation of equipment is not enough. To always have a margin of availability of energy, the batteries must be sized for several days of autonomy (more days of autonomy, more years will last because the depth of discharge will be lower).

3.1.6 Classification

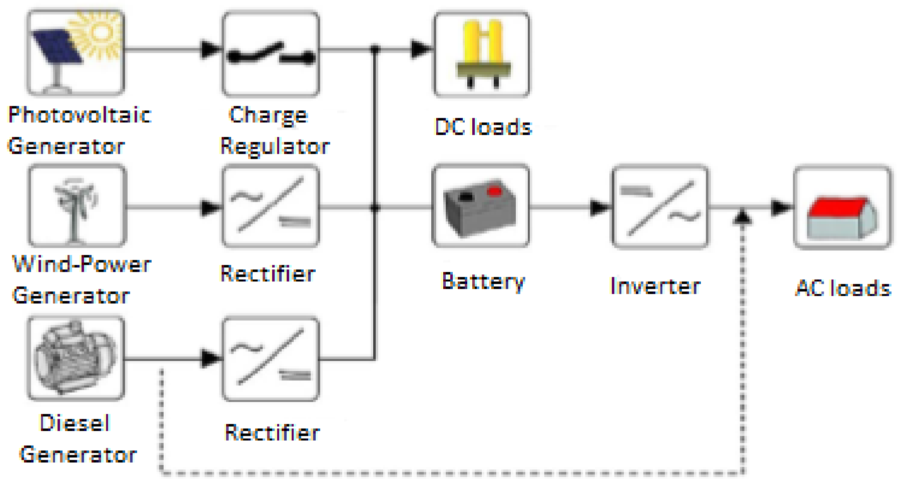
In relation to the type of electrical network of a microgrid, this can be a direct current network, an alternating current network or even a network of high frequency alternating current. The system can be single-phase or three-phase and can be connected at low or medium voltage level to the general electrical network.

The choice of the type of current (alternating or continuous) that is used for the operation of the system, depends a lot on the technologies used and on the energy management strategy. While photovoltaic generation and batteries operate in DC, other generation technologies, such as wind turbines or microturbines, normally produce in AC.

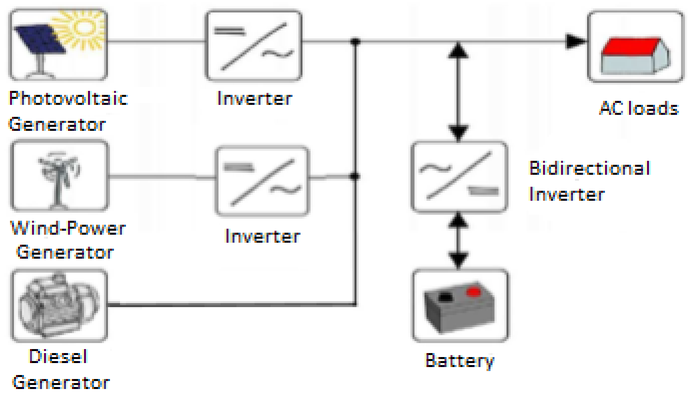
Next, we will see schematically the main systems that could be used in this type of applications, depending on the type of current used in the generator discharge bus. [5]



Example of DC bus configuration.



Example of DC bus configuration with DC loads.



Example of AC bus configuration

In the previous figures you can clearly see the type of current in which the different generators produce, as well as the form of interaction with the rest of the subsystems. Therefore, the configuration of the future microgrid should begin by determining the best possible electrical architecture based on the present and future needs of the consumptions that are intended to be electrified, considering the degree of maintenance and technical capacity of those responsible for the operation and maintenance, for the sake of final sustainability.

Within the exposed systems and as a general rule, both the DC bus case and the DC bus with DC loads are usually more used in small systems and with a number of users not too wide or distant between them. The last option, bus in CA, is used more frequently to supply a greater number of users and with greater geographical dispersion, supporting better possible expansions and admitting new generation incorporations, even in a distributed way among different consumers.

The first configuration is the most basic case, where the generation sources discharge their production in a battery, which through a DC / AC inverter feeds the different consumptions. The control of the system is very simple, so much so that in many cases it is limited to the starting of the diesel backup when the battery charge level is low or when a specific energy supply is needed, but never comes into direct electrical contact with the consumptions. These are simple systems, but quite reliable and are designed primarily for small zonal distribution networks and controlled consumption.

The following configuration is the same as the previous one, but it incorporates a direct DC output that could feed some kind of DC loads when the battery is fully charged (for example, water pumping systems) thus avoiding losing that available energy that would not be used in the case of not having this type of alternative. The function of the diesel backup in this case would be the emergency power reserve (as in the previous case), with the additional possibility of also directly supplying the AC loads, as well as safety in the event of a DC / AC inverter failure, either in parallel with the inverter as long as it was designed to work in this way and both the inverter and the control system have these functions implemented.

The last configuration is perhaps the most complex but versatile of all. For its operation there must be a more sophisticated control system that dictates the manoeuvres necessary for its perfect operation, starting or stopping the fuel backup when necessary, but always giving priority to the operation of the other energy sources or the discharge of the batteries to supply points of consumption or temporary situations of lack of production of alternative sources. These systems are more demanded and delicate in their operation and maintenance, needing a greater personal preparation to assist them.

3.1.7 Components

3.1.7.1 ENERGY SOURCES

From the possible sources we will focus on describing those that are going to be studied in our project. These are photovoltaic panels, wind turbines, micro gas turbines and fuel cells.

- **Photovoltaic panels**

Solar production depends on solar radiation at the site. To quantify the solar radiation incident on a surface, the irradiance is defined, which is the power density incident on a surface, or the incident energy per unit of surface unit, and is measured in kW / m2.

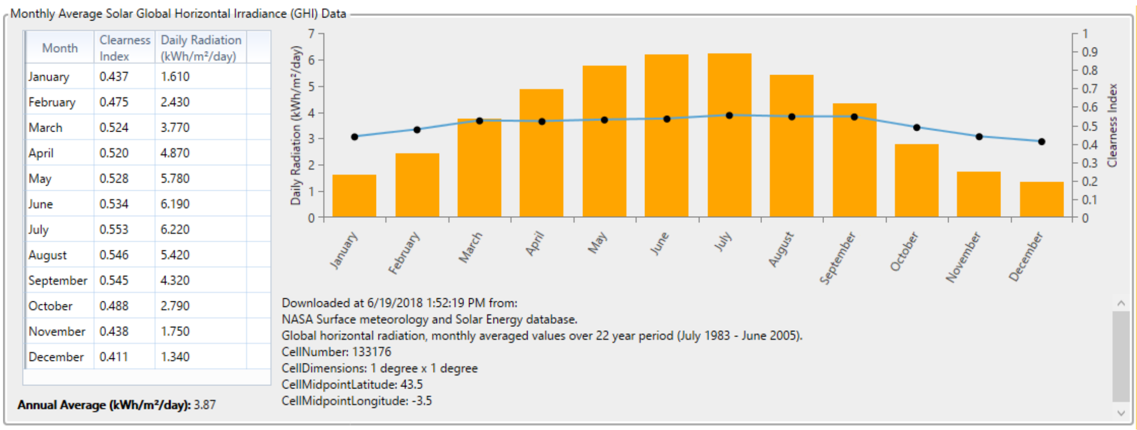
Photovoltaic energy is the direct transformation of solar radiation into electricity. This transformation occurs in devices called photovoltaic panels, in which the solar radiation excites the electrons of a semiconductor device generating a small potential difference (photoelectric effect). The series connection of these devices allows to obtain greater potential differences.

When sunlight hits the photovoltaic cells, the electrons tend to cluster on the illuminated face, generating a positive face and a negative face. By putting both faces in contact with a conductor, an electromotive force is created that generates an electric potential to equalize the charges; This is how electricity is produced. Photovoltaic cells produce DC current instantly.

One of the greatest challenges when studying the feasibility of an energy system in a specific location is to determine the potential resource of the region.

In our case we will determine the solar resource in the geographic location where the study area is located. For this I have had access to data from NASA that has been accumulating for several years and it is shown as a monthly average.

The data shown below corresponds to horizontal radiation over 22-year period (July 1983-June 2005). So, we can consider that they are very reliable data.



Average monthly radiation

The daily radiation is presented together with the respective index of clarity. The annual average radiation is 3.87 kWh/m^2/day. As is logical, we have a higher radiation in the months corresponding to the summer and a lower radiation in the winter months.

Below we have the radiation data obtained in the Spanish city of Alicante[7]. We can see that for an inclination of 35º photovoltaic panels, we obtain the best results, this inclination is similar to the latitude of the city (38º). So we can conclude that our panels will be inclined a number of degrees similar to the latitude of our village (43º) to receive the highest radiation during the year.

Alicante

Ang	En.	Fe.	Ma.	Ab.	Ma.	Ju.	Ju.	Ag.	Se.	Ob.	No.	Di.	R. Anual	Inviern
20	13.5	15.9	21.5	22.1	23.4	25.3	25.4	23.4	22.0	18.5	15.8	11.9	7161	2917
25	14.4	16.6	22.0	22.1	23.0	24.7	24.9	23.2	22.3	19.2	16.8	12.7	7260	3055
30	15.2	17.2	22.4	22.0	22.5	24.0	24.2	22.9	22.5	19.8	17.7	13.4	7316	3174
35	15.9	17.7	22.6	21.7	21.9	23.2	23.5	22.5	22.6	20.3	18.5	14.1	7331	3273
40	16.5	18.1	22.7	21.4	21.1	22.2	22.6	21.9	22.5	20.6	19.2	14.7	7302	3350
45	17.0	18.4	22.7	20.9	20.3	21.1	21.6	21.2	22.2	20.9	19.7	15.1	7232	3407
50	17.3	18.5	22.5	20.2	19.4	20.0	20.5	20.5	21.9	20.9	20.1	15.5	7120	3441
55	17.6	18.6	22.2	19.5	18.4	18.8	19.3	19.6	21.4	20.9	20.4	15.8	6967	3454
60	17.7	18.5	21.7	18.7	17.3	17.5	18.0	18.6	20.7	20.7	20.5	16.0	6775	3444
65	17.8	18.3	21.1	17.7	16.1	16.1	16.7	17.5	20.0	20.4	20.5	16.0	6545	3412
70	17.7	18.0	20.4	16.7	14.8	14.7	15.3	16.3	19.1	20.0	20.3	16.0	6279	3358

The characteristic curve of daily production has the shape of a bell, so that, in the morning, once the sun rises, the solar panel would begin to provide us with little energy, which would increase gradually as the sun rises, until reaching its maximum At the centre of the day, when the sun is fully in front of the panel and right from that moment, it would begin to provide less energy following the slope opposite to that of the morning until sunset.

As we know photovoltaic energy is the most used renewable energy, one of the cheapest and photovoltaic panels has a long life.

- Wind turbines

Nowadays wind energy is transformed into electrical energy, through the so-called wind turbines. The maximum usable energy that can be extracted from a wind turbine is limited around a theoretical value of around 59.3% (Betz limit) that represents the maximum performance of the wind turbines. [8]

As we have done with the photovoltaic energy, we will consult the Nasa database, to obtain the average wind speeds in our village every month of the year.

The database has been made between July 1983-June 1993. Wind speed at 50 m above the surface of the earth.

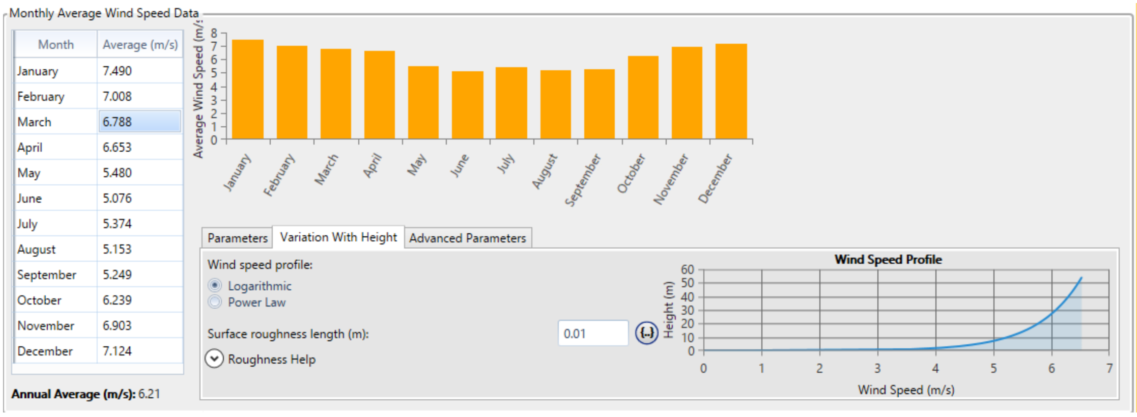
As the wind turbine model that we are going to use later has the rotor at a height of 36 meters, I have adapted this data to that height with the following formula. [9]

$$v = v_{ref} \cdot \frac{\ln(\frac{h}{h_0})}{\ln(\frac{h_{ref}}{h_0})}$$

Where:

- V_{ref} is the reference speed
- h_{ref} is the reference height
- h_0 height of the roughness of the ground, we us 0.01m (rough pasture)
- h height of rotor

Performing the relevant operation, the data obtained corresponding to the wind speed in the place and at the desired height are the following:

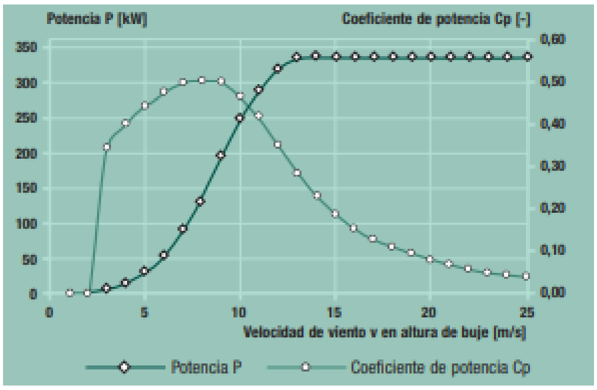


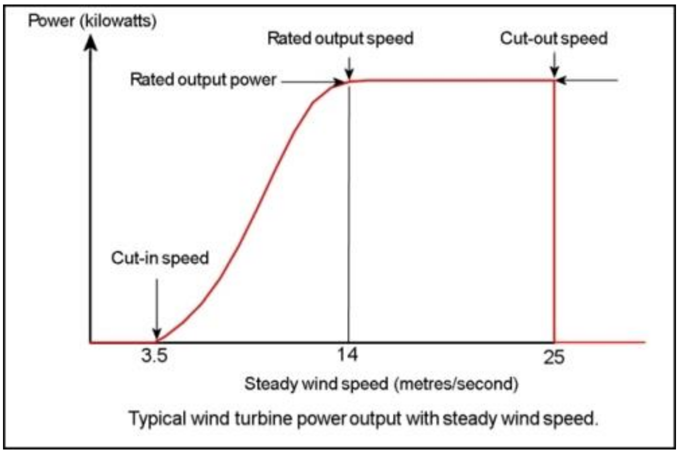
Average monthly wind speed

The annual average wind speed is 6.21 m/s and unlike what happened with solar radiation is in the winter months when the speed is higher.

The power provided by a wind turbine is characterized by its power curve, which gives us the relationship between wind speed and power produced. The power curve depends among other factors on the density of the air; at a higher density, the greater the power supplied. Normally all manufacturers give the power curve for the value of 1,225 kg / m3.

Next we have a power curve given by the manufacturer ENERCON [10]





Power curve of a wind turbine

We can describe the equation corresponding to the curve [11].

The equation of the first part of the curve is:

$$P = \frac{1}{2} C_p \rho A v^3$$

So, power extracted depends on:

1) Design factors
   - Swept area, A
2) Environmental factors:
   - Air density, ρ
   - Wind speed, v^3
3) Control factors affecting performance coefficient C_p (θ, λ):
   - Tip speed ratio through the rotor speed w
   - Pitch θ

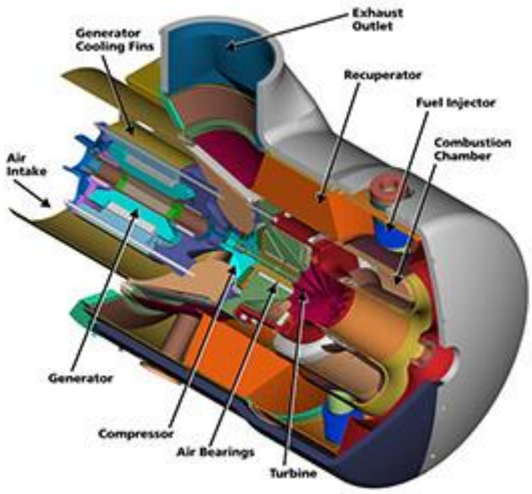
Below the nominal speed the production is proportional to the cube of the speed, so it is important to characterize well the wind speed of the site to be able to estimate the energy production. Going from a speed of 5 to 6.25 m / s would be the equivalent of having a wind turbine twice the area. However, there are certain limits because if the wind is very high (more than 25 m / s), the wind turbine must stop to prevent its destruction. And if the wind is very loose (less than 4 m / s), the wind turbine cannot start.

- Micro gas turbines

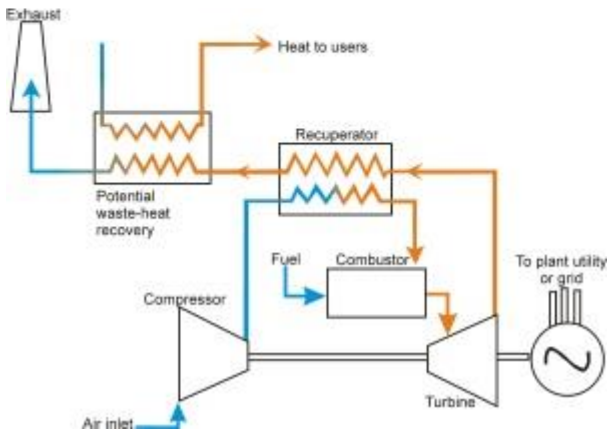
These are combustion turbines consisting of a compressor, a turbine, a recuperator and a generator, generally integrated in a single axis. Its main advantages are the limited number of moving parts, its compact size, its wide variety of sizes and that have lower emissions than a gas turbine. Likewise, they require minimal maintenance, are light and compact. The power range is between 15 kW and 300 kW. [12]

They have a permanent magnet generator rotating at high speed (80000 rpm typically), generating alternating current at very high frequency. These generators cannot be connected directly to the distribution network, so an inverter that rectifies this high frequency voltage must first be connected to the output, generating an alternating signal compatible with the electrical distribution network or microgrid in our case.

The following images show the main construction parts of a microturbine and a schematic representation of its operation. [13]



Parts of a microturbine



Functional scheme of a microturbine

The compressor is responsible for compressing the ambient air, which is heated in a heat recovery, thus increasing the efficiency of the microturbine. The preheated compressed air is mixed with the natural gas, and an electric ignition device located in the combustion chamber ignites the mixture. When leaving the chamber, the combustion gases expand in the turbine and its pressure and temperature decrease. The electrical energy is generated by a high speed synchronous permanent magnet alternator, which is integrated in the microturbine.

- Fuel cells

Fuel cells are devices capable of converting chemical energy, directly, into electrical energy. This technology is based on a chemical reaction in which, from a fuel source, such as hydrogen, and an oxidant, water, heat and electricity are generated. Fuel cells have a very high conversion efficiency compared to conventional technologies (35-65%). The combustion only releases water vapor, free of CO2 and allow a great security of supply. Multiple combinations of fuel and oxidant are feasible. [14][15]

The basic unit of a fuel cell is what is called "mono cell" or "cell". A cell is formed by a cathode (positive electrode) and the anode (negative electrode), which are separated by an electrically conductive medium (electrolyte). The electrolyte acts as an electrical insulator but allows the transport of the ions (H +) between the electrodes.

These cells produce a potential difference somewhat greater than one-volt open circuit, so if you want to reach higher voltages is necessary to have these cells in series. This stacking, with the propitious structure to evacuate the heat generated, is known as a fuel cell.

To understand the operation of this technology, the electrolysis process will be explained. Electrolysis is a process by which water is separated into oxygen and hydrogen by applying electricity.

$$H_2O + electricity \rightarrow \frac{1}{2}O_2 + H_2$$

This electrolysis reaction is reversible and fuel cells are based on this peculiarity.

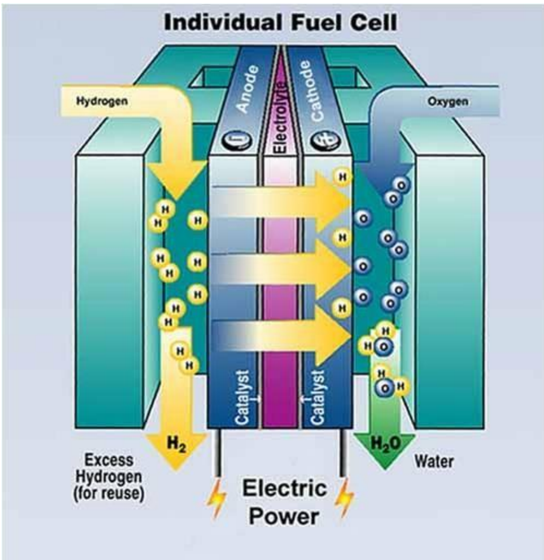
The hydrogen is supplied to the anode where it dissociates, in e- and H + electrons, in the presence of a catalyst.

$$2H_2 \rightarrow 4H^+ + 4e^-$$

At the cathode, the hydrogen ions, oxygen and electrons recombine forming water molecules.

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O + electricity$$

The following figure shows a diagram of the operation of a fuel cell for the described electrolysis process.



Mode of operation of a fuel cell

The fuel cells generate electric power in direct current that must be transformed into an alternative by means of an inverter.

3.1.7.2 STORAGE SYSTEMS

The decoupling that can exist between the curves of generation and demand forces that there must be storage systems that allow to solve this possible lag in a simple and effective way.

The availability of energy storage methods is the only way to store the renewable excess in the area where the microgrid is located. In this way, this excess at certain times of the day can be used to support the deficit of generation that could occur at other times.

Consequently, we will need storage systems to support consumption from a few minutes, up to whole hours and this is precisely the problem, the accumulators are not cheap and also have a limited life, which forces us to have to replace them probably during the expected life of the rest of the installation.

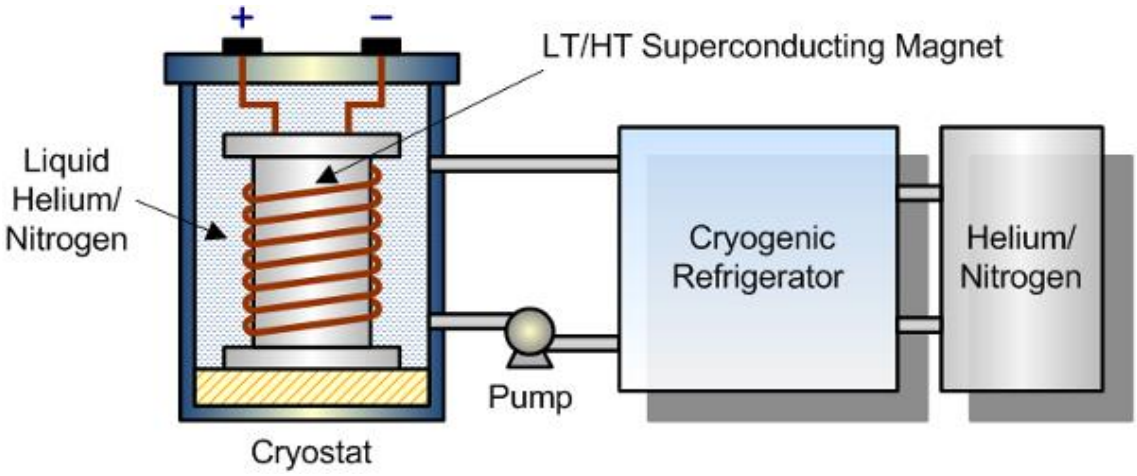
Therefore, we are facing the real technical challenge, achieving the perfect balance between the different renewable sources, an accumulator as small as possible and a poor functioning of the backup group. We should also act, as far as possible, adapting the loads and their operation to the expected production profiles. This aspect, often forgotten, is essential to complete a perfect design.

Next, we will analyse the main storage systems that can be incorporated into a microgrid. [16]

- Storage in magnetic superconductors (SMES)

SMES systems store electromagnetic energy with insignificant losses by circulating direct current through superconducting cryogenically cooled coils. The stored energy can be injected back into the network by discharging the coil. [17]

The system uses an inverter / rectifier to convert alternating current to direct current or vice versa. The inverter / rectifier presents energy losses close to 2-3% in each direction. SMES have lower electricity losses, inherent in the conversion, compared to other methods of energy storage, such as batteries or flywheels, with theoretical efficiencies close to 95% in large installations.



Scheme of Superconducting Magnet

The high cost of superconductors is the main limitation for commercial use. Due to the energy needs of refrigeration and its high cost, SMES are currently used for the storage of energy for short periods of time. It is a very attractive technology for high powers with fast discharge times.

SMES storage systems have an average maturity, a long service life, an average cost per kWh and a low installation cost.

- Supercapacitors

This technology stores electrical energy in the form of electrostatic charges confined to small devices. These devices are formed by pairs of conductive plates separated by a dielectric medium. [18]

They have the ability to be charged and discharged in a few moments of time, in the order of seconds, which makes them very appropriate to respond to short interruptions. They have a long life, more than a thousand cycles of charging and discharging with a high performance, close to 100%, providing a time of discharge of instants, but with a limited energy density.

The storage system with supercapacitors has a low maturity, a long service life, an average cost per kWh and a low installation cost.

- Flywheels

They consist of a central axis that moves a rotor and a flywheel. They store energy kinetically by accelerating the rotor and the flywheel at a very high speed and releasing energy by reversing the charging process, using the motor as a generator. [19]

Modern flywheel systems are composed of a high-rotation cylinder with magnetic levitation bearings which eliminate wear and prolong the life of the system. To increase efficiency, the steering wheel is used in a low-pressure environment to reduce friction with the air.

Depending on the speed of rotation they are classified into low or high-speed flywheels. The low speed flywheels usually have relatively low rotation speeds, around 10,000 rpm and a heavy steel rotor. They can provide up to 1650 kW, but for a very short time, up to 120 s.

When the rotor speed increases, the systems are known as high speed flywheels with speeds of about 80000 rpm. They can provide power for up to an hour, but with a maximum power of 750 kW.

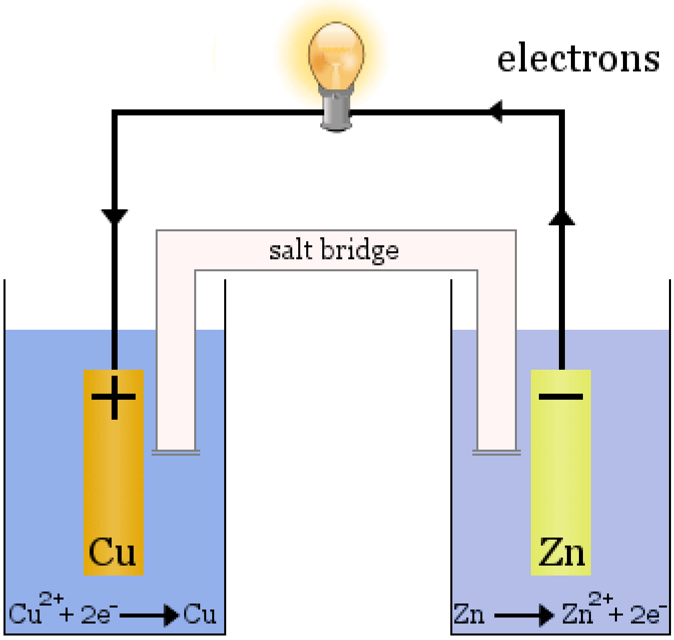
Flywheels have an energy density of 50-100 Wh-kg and an efficiency of around 90%. They have a useful life of about 20 years or tens of thousands of cycles. In general, flywheels are used for power quality improvements, as an uninterruptible power supply and to dampen frequency variations.

The storage system with flywheel has a medium maturity, a long service life, an average cost per kWh and an average installation cost.

- Electrochemical batteries

This technology is currently widely used in microgrids. They are rechargeable systems in which electrical energy is stored in the form of chemical energy, composed of an electrolyte, a positive electrode (anode) and a negative electrode (cathode). During the charging period, by applying a potential difference between the electrodes, electrically charged ions are generated and during the discharge they are used to create a flow of electrons through an external circuit.

Electricity is produced in direct current, and for application it is normally converted to alternating current by means of an inverter.

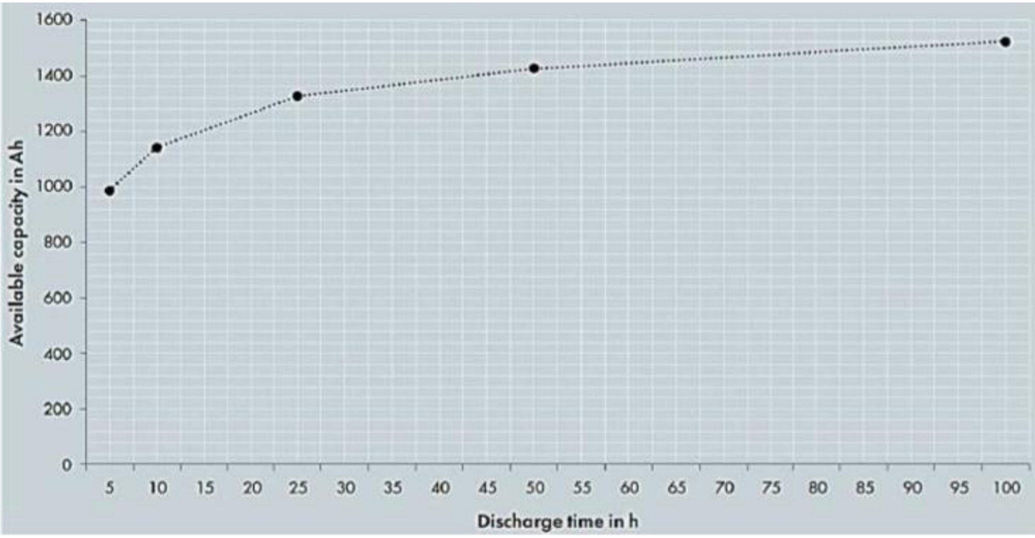


Scheme of an electrochemical battery

Batteries are generally expensive, require a lot of maintenance and have a limited service life.

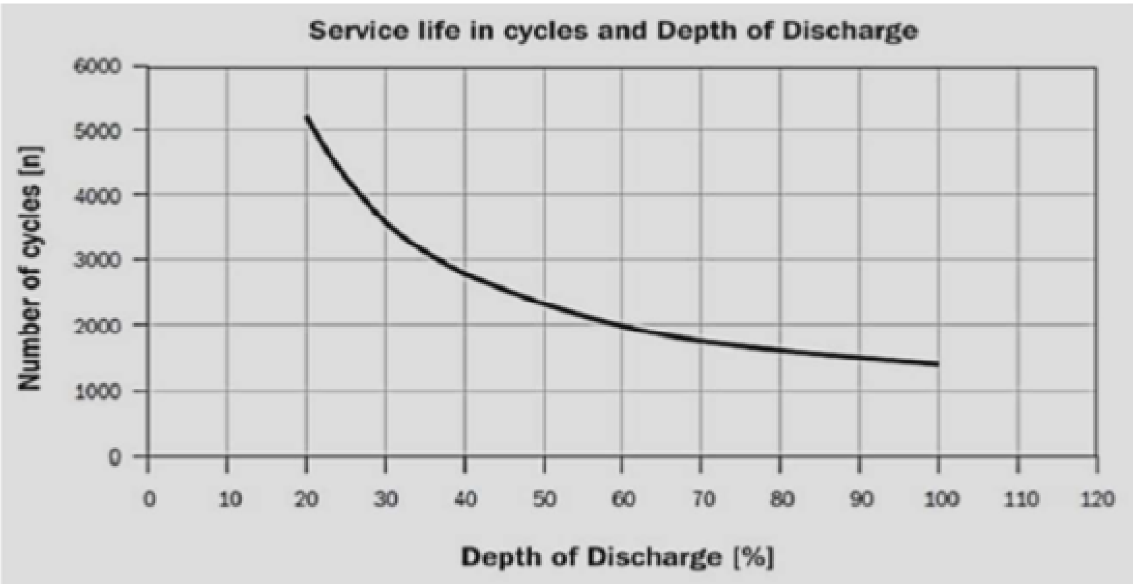
Depending on the type the storage system with batteries has a medium (NaS) or high maturity (lead-acid or NiCd), a low useful life (lead-acid), medium (NiCd) or high (NaS), a cost per kWh medium and an average installation cost.

- Characteristic parameters [21]
- *Ampere hour capacity* is the number of amps that a battery provides for the number of hours during which the current flows. However, in a given battery the capacity will be lower the faster we download it and we will use in the designs the capacity that adapts to the speed of discharge that is needed.



Example of the relationship between discharge time and battery capacity

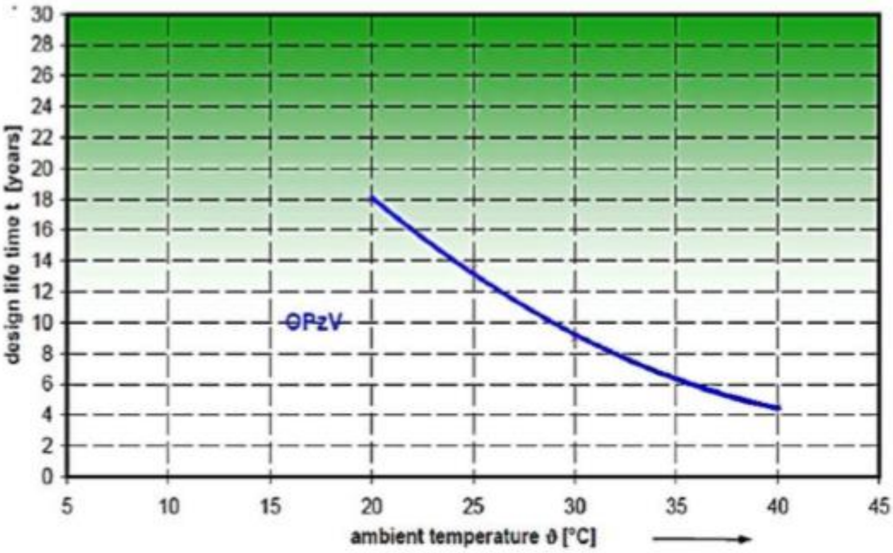
- *Depth of discharge:* the percentage of the total capacity of the battery that is used in the discharge process. The greater the depth of discharge, the smaller the number of cycles that can be obtained from it.



Example of the relationship between the depth of discharge and the number of life cycles.

- *Effect of temperature:* if we work at low temperatures, the internal resistance increases, and the output voltage decreases. If we work at high temperatures, efficiency increases slightly, but there is a drastic reduction in the useful life.

This last situation is by far the most pernicious one that we face, therefore, we must locate and maintain the batteries in a place where we can ensure the most stable temperature possible in the environment of 20-25 ^{0}C so that the useful life of the accumulator is the highest possible.



Relationship between temperature and battery life

These concepts are fundamental for calculations and the choice of the best possible accumulator that meets our needs, so we must always keep them in mind.

- Flow batteries

They are a type of batteries in which the electrolyte contains in solution one or several electroactive spices that circulate through the reactor, converting chemical energy into electrical energy. [22]

The reactions that take place in the reactor are reversible and, therefore, the batteries can be charged and discharged. These systems have a long service life, but their current density is usually low due to the limited solubility of the active materials. Its capacity can be varied by increasing or decreasing the amount of electrolyte.

One of the biggest advantages they offer is their high efficiency in storage and conversion (around 85%), as well as their low response time.

Regarding standard batteries, they have the advantage that in these systems the energy capacity, related to the volume of electrolyte is given by the volume of the external tank, is independent of the power, which is a function of the reactor size. However, they are more complicated than standard batteries, since they require pumps, sensors, control units and external tanks.

- Comparison of storage technolgies

In the following table we can see a comparison of different storage technologies.

Technology		Power density [W/kg]	Energy density [Wh/kg]	Daily self-discharge rate (%)
Battery	Lead-Acid	75-300	30-50	0,1-0,3
	NiCd	150-300	50-75	0,2-0,6
	NaS	150-230	150-240	20
	ZEBRA	150-200	100-120	15
	Li-ion	150-315	75-200	0,1-0,3
Flow batteries	VRB	-		Negligible
	ZnBr	-		Negligible
	PSB	-		Negligible
Flywheels		400-1500	10-30	100
Capacitors		100000	0,05-5	40
Supercapacitors		100000	2,5-15	20-40
Superconductors		500-2000	0,5-5	10-15

Comparison of different energy storage systems

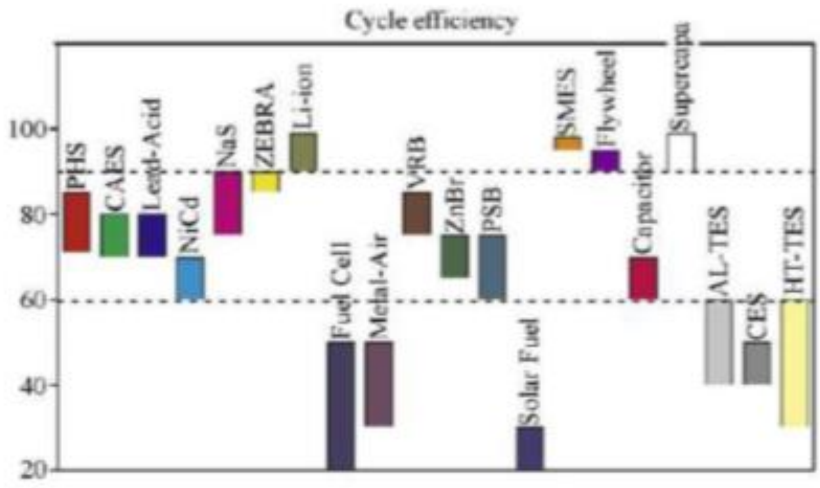
On the one hand, the energy density of superconducting technologies, capacitors and supercapacitors, as well as flywheels is very low. However, its power density is high which implies that these technologies are suitable for quality supply applications with high power transfer rate and short response times.

On the other hand, electrochemical batteries and flow batteries have average levels of power density and energy.

In relation to the daily self-discharge rate, those storage technologies whose rate is less than 1% such as lead-acid batteries, NiCd, Li-ion, flow batteries, are suitable for medium-long-term storage (tens of days).

Technologies with high rates of self-discharge, between 10 and 40%, are suitable for short-term storage (hours). The self-discharge rate of flywheels indicates that the stored energy will be lost if the storage period is greater than one day. These devices are suitable for energy storage in the order of minutes.

Comparing the efficiency of the charge-discharge cycle, understood as the quotient between the electrical energy supplied to the storage device in a complete charge cycle divided by the electrical energy obtained in a complete discharge cycle, the following picture shows this value graphically for different technologies. [21]



Complete cycle efficiency of charge-discharge for various storage technology

The previous picture shows that the Li-ion batteries have very high efficiency, while the rest of the electrochemical and flow batteries have efficiency values between 60% and 90%.

Useful life of storage technologies can be indicated by the number of years or by the number of cycles during the device will be operational. The storage technologies have a limited useful life associated with the chemical deterioration of the units over time.

Technology		Useful life [years]	Equivalent cycles [cycles]
Batteries	Lead-Acid	5-15	500-1000
	NiCd	10-20	2000-2500
	NaS	10-15	2500
	ZEBRA	10-14	2500+
	Li-ion	5-15	1000-10000
Flow batteries	VRB	5-10	12000+
	ZnBr	5-10	12000+
	PSB	10-15	

Comparison of the useful life of different types of batteries.

The table shows the useful life for some technologies and it is verified that flow batteries have a longer useful life than electrochemical batteries.

In addition to the technological parameters analysed above, such as cycle efficiency and useful life, the parameters of investment cost per unit of transferred electrical power and investment cost per unit of stored energy determine the degree of implementation of a specific storage technology.

Combination of different types of batteries in the same microgrid is an interesting option, including batteries that provide a high power in a few seconds, e.g. Li-ion along with others that deliver a lot of energy for long time, e.g. flow batteries.

3.2 OPERATION OF MICROGRID CONTROL SYSTEM

[IEEE 1547.4-2011] standard defines a micro grid as "*an electrical system that has different distributed generation resources, multiple loads, operates in isolated mode or interconnected to the grid and can operate with bidirectional power flows*".

Generally, microgrids work with distributed generation based on non-conventional renewable energies, which through power electronics adequately condition their energy delivery. These types of generators have experienced an important development in recent years, being wind and solar energy, the industries with highest projection and fastest growing in the renewable energy sector and which are currently called to be fundamental in the distributed generation of microgrids.

3.2.1 Manageable and non-manageable generators

In terms of power flow control, a generating unit may be manageable or non-manageable. The output power of a manageable micro generator can be controlled externally, through operating points defined by a control system. An example of a manageable generation unit is a generator that uses an internal combustion engine as its primary energy source.

This kind of generators have a control system to adjust the speed based on the flow of fuel. The automatic voltage regulator controls the voltage of the synchronous generator. In this way, the control system and the voltage regulator control the outputs of active and reactive power based on the management strategy.

In contrast, the power output of a non-manageable micro generator is normally controlled in the optimal operating condition of its primary energy source, for example, a wind generator is operated with the aim of extracting maximum power from the wind regime to which he is subjected. In this way the power delivered by the machine varies according to the wind conditions at each moment.

Micro generation units that are based on renewable energies are often lack control capacity units. To maximize the output of a micro generation source based on renewable energy, a strategy based on tracking the maximum power point (MPPT) is normally applied in order to deliver the maximum power.

3.2.2 Control strategies

In isolated microgrids, the stability of frequency and voltage are not assured, appearing important technical challenges for the control systems. Control strategy most used in these cases is known as Droop Control, which regulates the frequency through active power, while the voltage is controlled with reactive power. [23]

In this situation the inverter is controlled to feed the load with predefined voltage and frequency values. This control strategy emulates the behaviour of a synchronous machine, controlling voltage and frequency on the system.

In Droop Control the inverter acts as a voltage source, with the magnitude and frequency of the output voltage controlled by a regulator with a response like a primary regulator of a conventional network.

The distributed generators involved in the microgrid use their active power to set the frequency of the microgrid. Therefore, the frequency acts as a signal of communication between the distributed generators. In this way each controller of the micro generators must respond autonomously and effectively to changes in the system without requiring data from the loads.

As for the Active Power - Frequency relationship, the Droop Control strategy relates Reactive Power - Voltage through a straight line with a determined slope. That is, in the event of a drop-in voltage, the Droop Control increases the reactive power, otherwise, reactive power is decreased / consumed to increase the voltage.

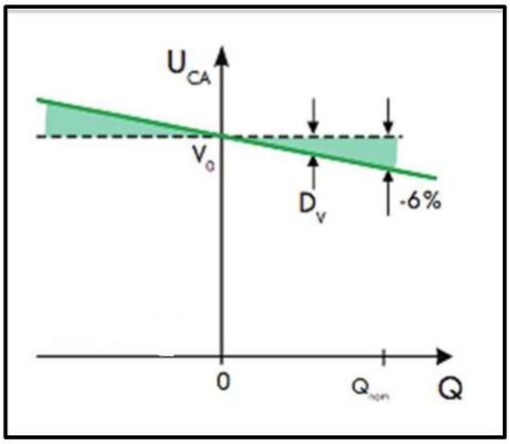
The Droop Control strategies mentioned are detailed below: [20]

- Voltage vs Reactive Power (Q) control:

It is the voltage regulation necessary for local reliability and stability. Without local voltage control, systems with high penetration of micro generators could experience voltage and / or reactive power oscillations.

The voltage control must also ensure that there is no large reactive current circulation between micro generators. With small errors in the voltage levels, the circulating current can exceed the ranges of the micro generators. This situation requires a voltage vs reactive power controller, such that as soon as the reactive power generated by the micro generators becomes more capacitive, the local voltage level will be increased.

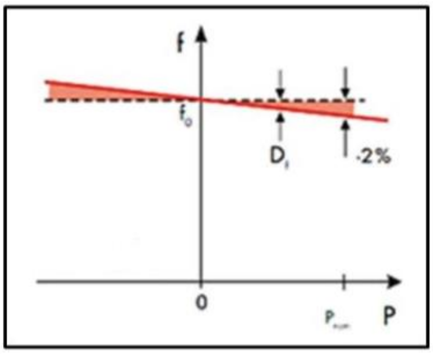
A generator has capacitive behaviour whenever it generates reactive and the more reactive it generates the more it contributes to increase the voltage in generation terminals and in the rest of the electrical points of the network to which it is connected. Conversely, as Q becomes more inductive, the voltage level will be reduced.



Voltage vs Reactive Power

- Frequency vs Active Power (P) control:

When regulating the power output, each source has a negative slope in the P plane. The attached figure shows the relationship between frequency and active power defined for a generator. As the frequency decreases, the active power generated increases.



Frequency vs Active Power

3.2.3 Application of microgrid inverter control

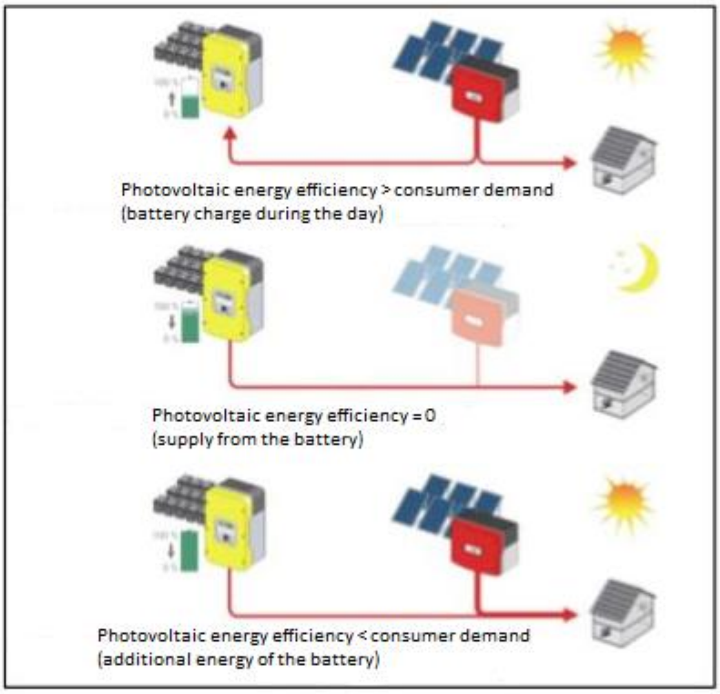
If there are no synchronous machines, the frequency control must always respond to the needs of balancing demand and supply. Therefore, a voltage control strategy is required to avoid oscillations in the microgrid. The voltage and frequency references obtained through voltage source control allow operating the microgrid in isolated mode.

Inverters can provide the flexibility needed for simplified control. From the practical point of view, it is necessary to consider that the future expansion of a microgrid will not imply the modification of the control system defined initially. The interfaces of the inverters that are located in the fuel cells, micro turbines and storage technologies will be the basic elements of the tele control system.

A key element of the control design is that the communication between micro generators is not necessary for the basic operation, since this information will be managed by the inverter. Each controller must be able to respond effectively to system changes without requiring data from loads or other sources.

In general, the operation of the system is carried out by defined limit values, which are pre-established in charge regulators or battery inverters.

In a simplified way, the control of microgrids can be explained graphically, for better understanding, from the following figure. We see that the main element consists of a reversible equipment that acts normally as an inverter (DC / AC) but that at certain times becomes a battery charger (AC / DC) so that we are in front of a bidirectional team.



Example of microgrid way of control

The inverter is connected directly to an accumulator, thus constituting the network of the isolated system and regulating the voltage and frequency on the AC side, where the generators (in the example represented by a photovoltaic system) and consumers are directly connected.

If the generation is greater than the consumption, the inverter changes its operating mode and becomes a charger, extracting energy from the network and charging the batteries. When there is an energy deficit, it returns to the inverter function, returning power to the grid from the batteries.

When it is acting as a charger and only in the case that the batteries reach their full charge, it returns to the inverter function and automatically increases the frequency of the network, in order to get the inverters connected to the photovoltaic generation to reduce their production adapting to the level of consumption demanded by the distribution network.

3.3 DEMAND MANAGEMENT

3.3.1 Management of the demand of an electrical system

Demand management is the planning and implementation of those measures designed to act on the side of energy consumption, so that the desired changes in the demand curve occur. The main objective is to achieve a more homogeneous electricity consumption throughout the day.

Demand management can help to balance the electricity system, for example, in case of forecast errors in the generation of variable renewable energy.

The different mechanisms of demand management that can contribute to achieve the desired effect can be grouped into four large blocks: [23]

- The consumption reduction group is aimed at reducing globally the demand for electrical energy, without specifying when this reduction occurs.
- Measures included in the displacement of the consumption from the tip to the valley, thus achieving the adaptation of the curve of the demand to that of the supply.
- The filling of valleys has as objective that the incorporations of the new demands of the system take place preferably during the moments of lower demand.
- The tips reduction mechanisms are aimed at obtaining a resource available for the operation of the system in emergency situations.

3.3.2 Management of the demand of a microgrid

The principles outlined in the previous section can be applied, on a small scale, in the microgrid environment.

The management of the demand according to the characteristics of the place and the habits of the future users of the microgrid, is a key element for the sizing of generators and accumulators. Demand management allows the user to intelligently use the energy available in networks whose generation is limited or pulsating, such as those made with renewable energy sources. You cannot consume more energy daily than the one that has been generated and accumulated.

Therefore, the design must adapt to the expected consumption profile and must be accompanied by a good and exhaustive information of future users, in the use and enjoyment of the electrification of which it will be a beneficiary, in addition to the technical control of the system itself.

The management of the demand cannot be effective without the active participation of the client / user. For this, it is essential that it be fully aware of the way in which it is consumed, the price of the energy it consumes and the options available for its reduction, thus influencing how much electricity is used and when it is used.

This fact requires providing customers with information terminals, as well as the possibility of making manual reconnection orders or modification of rates, contracted power, etc.

Next, a series of measures are taken into account in order to guarantee an adequacy of the demand to an established microgrid, optimizing the use of the available resources: [20]

- Initial delimitation of the service at X daily hours.
- Limitation of power in each house or consumer.
- Mandatory use of energy saving lamps.
- Prohibition of certain charges (electric stoves, stoves, etc.)
- Installation of energy limiters in houses with excessive consumption.

All this with the pretension of being able to have a supply of electric power with minimum conditions of quality and reliability.

3.4 DEMAND ESTIMATION

One of the most important actions in the implementation of any energy system is the estimation of the load. This is done simply by calculating the most probable load profile of the field of study.

It is crucial to note that the load varies according to the time, day and seasons, and that the power system must be able to provide this demand always. Another important factor that should be considered in the estimation of loads is that in addition to satisfying the needs of the consumer, one should try to minimize the probable losses of energy.

In this study, the village to be electrified consists of 130 homes and a milking parlour. As we have seen before the level of electrification is 9.2 kW for homes and 18.4kW for the milking parlour.

Thus, the profile for a home is estimated and the total charge is calculated. Assuming that the demand is the same for all.

The preferred method to estimate the loads is to observe the power of each equipment and multiply it by its hours of use, in order to obtain the consumption in watts hour.

For certain types of loads, it is often difficult to anticipate their consumption. Applications such as television and appliances consume energy even when they are turned off. For this reason, it is necessary to introduce a correction factor of 1.1 or 1.2, also including the connection and wiring losses.

By consulting several websites of Spanish energy companies, you can get the most common loads in a Spanish home. In addition to its average daily hours of use throughout the year and its average nominal powers.

In this way you can get the energy demanded by all the houses in the village daily. All this is summarized in the following table.

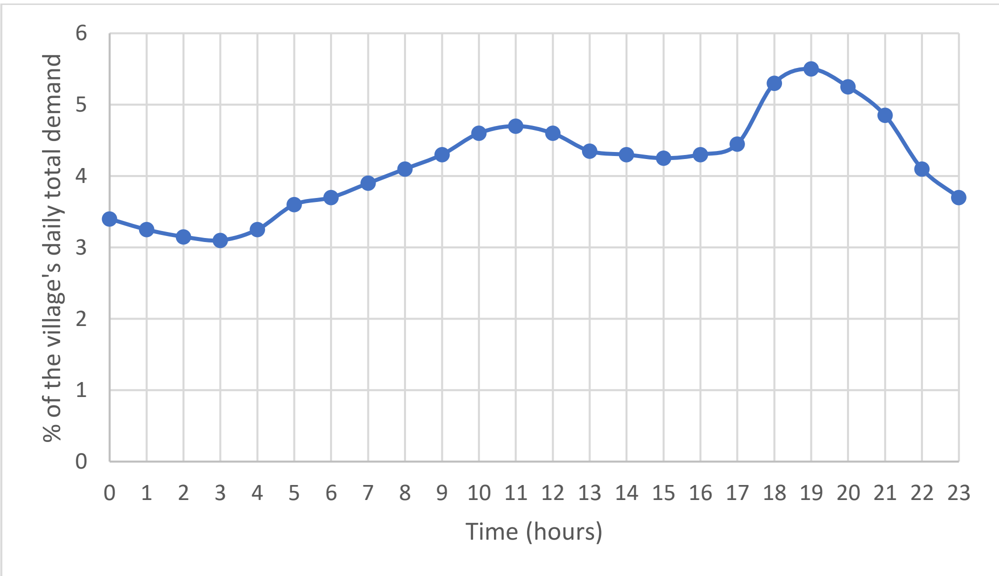
Load	Unit power (W)	Hours/day	Daily home energy (kWh)	Daily village energy (kWh) (130 homes)
Lighting	240	6	1,44	187,2
Cooktop	1200	1	1,2	156
Washing machine	330	1	0,33	42,9
Refrigerator	350	10	3,5	455
Oven	1300	0,5	0,65	84,5
Television	200	8	1,6	208
Dishwasher	1500	1	1,5	195
Computer	100	6	0,6	78
Microwave	1100	0,2	0,22	29,9
Iron	1350	1	1,35	175,5
Air conditioner/Heater	1300	4	5,2	676
Other consumptions	230	8	1,84	239,2
Total	9200		19,44	2527,2

Homes' daily energy demand

The power installed of each house is 9200 W and its daily consumption is approximately 19.5 kWh.

Multiplying by the total number of homes we know the consumption of the village.

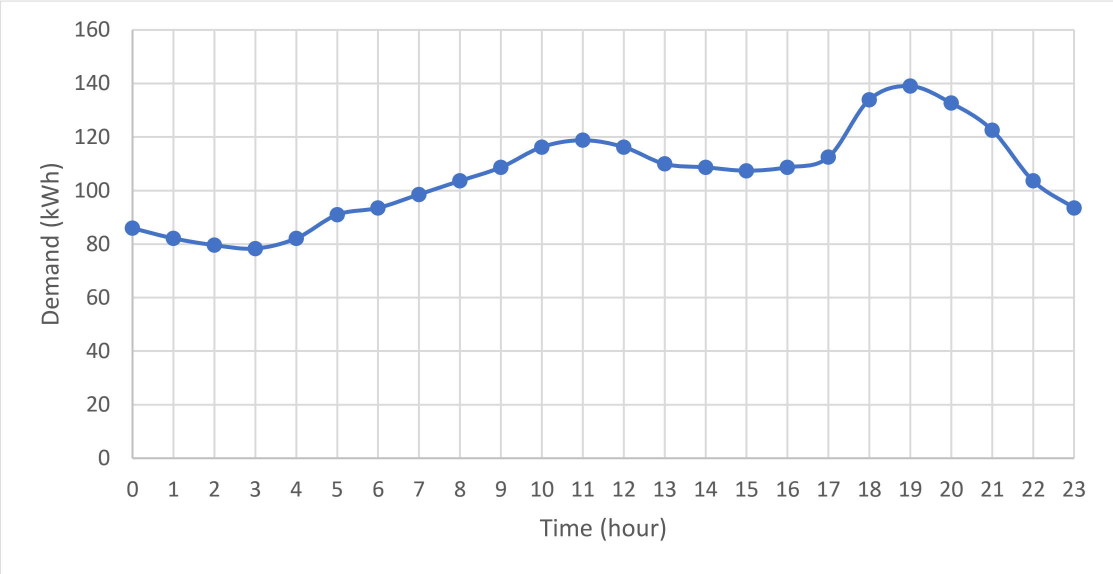
I have also been able to obtain a graph of the average demand per hour in a day in Spain expressed as a percentage of total energy consumed. That we can extrapolate to our area of study. [24]



Percentage of the total consumption demanded per hour

It could be observed that there are peaks of consumption at midday and after sunset. Having less consumption in the night hours.

Since we know the total daily demand we can apply the corresponding percentage to each hour to obtain the daily energy consumption profile expressed in kWh



Daily demand per hour

The highest peak of consumption occurs at 19, almost 140 kWh, there is another peak at 11, almost 120 kWh and the point of least consumption is at 3.

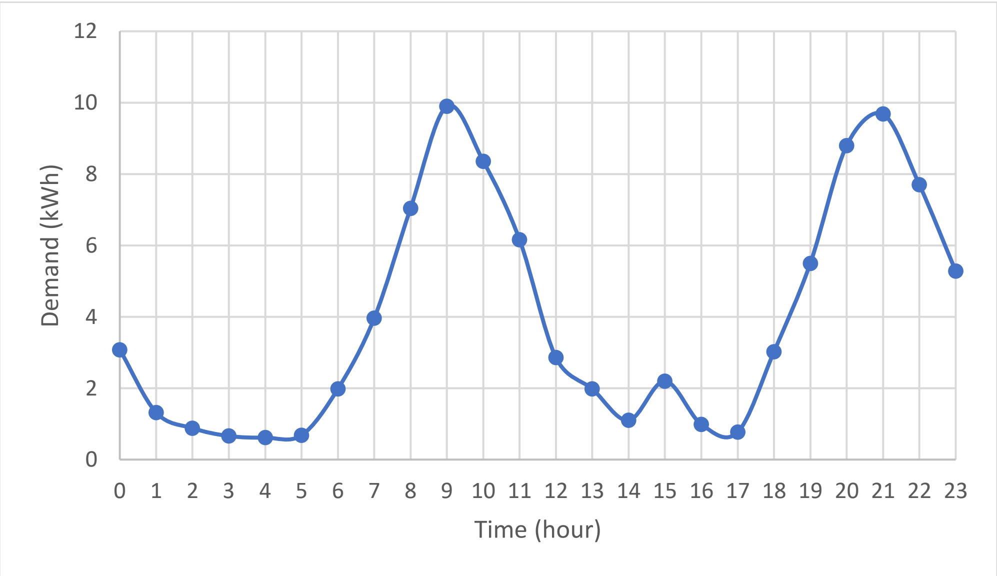
To this must be added the consumption of the milking parlour. As the number of cows is unknown I have reviewed a report of the characterization of energy consumption throughout the day in 61 milking parlours in a region of Spain. [25] In which you can get the average consumption per hour and per litre of milk of all of them, which I will apply in this project.

In this report it is established that the average number of litres of milk obtained per day is 2200 l. so we can calculate the consumption per hour.

Hour	Wh/l	kWh
0	1,4	3,08
1	0,6	1,32
2	0,4	0,88
3	0,3	0,66
4	0,28	0,616
5	0,31	0,682
6	0,9	1,98
7	1,8	3,96
8	3,2	7,04
9	4,5	9,9
10	3,8	8,36
11	2,8	6,16
12	1,3	2,86
13	0,9	1,98
14	0,5	1,1
15	1	2,2
16	0,45	0,99
17	0,35	0,77
18	1,375	3,025
19	2,5	5,5
20	4	8,8
21	4,4	9,68
22	3,5	7,7
23	2,4	5,28
Total		94,523

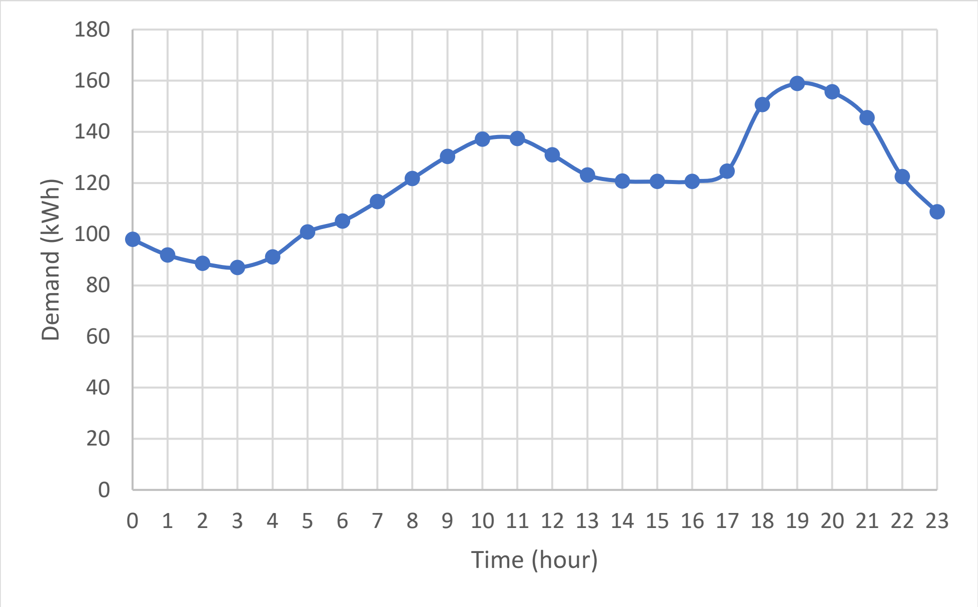
Milking parlour consumption per hour

We know that the total consumption is 94.523 kWh and from the table we can obtain the following graph.



Milking parlour consumption per hour

Now is the time to add the consumption of the homes and the milking parlour to finally get the total consumption that must supply our microgrid. The result is the following, adding the correction factor discussed above.



Total demand of the village per hour

The total daily demand is 2883,8953 kWh and the peak of consumption is approximately 160 kWh at 19h. Despite having introduced the demand of the milking parlour we see that the graph does not change too much.

3.5 SYSTEM OPTIMIZATION

3.5.1 Method description

The optimization model will be calculated using the software HOMER is a computer model developed by the National Renewable Energy Laboratory (NREL) to facilitate the comparison of energy generation technologies. HOMER physically models the behaviour of a power system and its cost in the life cycle, which is the total cost of the installation, plus the operation and maintenance of the system throughout its useful life. HOMER allows to compare many different design options based on their technical and economic advantages.

First we must enter the demand per hour previously estimated (kWh) as input data for the determination of the optimal solution.

The second step in the optimization process of the isolated system is to download in the software the radiation and wind data. Once this is done, the characteristics of the components that we have selected must also be introduced and the simulations carried out. Several parameters must be taken into account in order to optimize the system and have a comparison criterion. These parameters are listed below:

- System cost (initial investment, O&M, total NPC..)
- Renewable fraction
- Operating reserve
- Resource availability
- Maximum annual capacity of shortage

One of the crucial factors to be decided is the cost of each component. The initial investment, the operation and maintenance costs and the replacement costs are considered in the cost analysis.

3.5.2 Factors that affect the optimization process

In this section the costs of the different components are analysed. In the HOMER software, costs can be categorized into two groups. The first group consists of the initial investment, operation and maintenance (O & M) and replacement costs. The second group includes the net costs (NPC-net present cost), the total initial capital and the energy cost (EOC). These terms are briefly described in the following paragraphs.

- Initial investment cost

The initial investment cost of a component is the total cost of it once installed at the beginning of the project. The corresponding values of each equipment are shown in the table at the end of this section, together with the values of other parameters.

- Operation and maintenance costs

This term represents the annual cost of the maintenance and operation of each equipment. Like the other terms, their values are shown in the corresponding table.

- Spare/replacement costs

This cost is the price of the replacement of the equipment at the end of its useful life. This price may differ from the initial price for various reasons. For example, it may not be necessary to replace all the components of the equipment or its price may have decreased over time. In order to estimate these costs, the following estimates have been taken into account:

  - It is not considered a complete replacement of the installation.
  - The price of the components follows a line of decreasing tendency, in agreement with what happened in the last decade. This fact is feasible thanks to the current research, both in the photovoltaic and wind fields and in the energy storage systems.

The cost of investment and replacement and maintenance of wind energy and photovoltaics are shown in the following table.

For batteries and converters, it is assumed that they will have to be replaced in their entirety, so their replacement costs are assumed similar to the value of the initial cost and without maintenance costs. [26]

For micro gas turbines and fuel cells the price will be determined with help of the software.

System	Initial cost/W	Yearly O&M	Replacement cost	Useful life (years)
Photovoltaic	1,5€/W	0,1€/W	1,3€/W	20
Eolic	3€/W	0,375€/W	1,8€/W	20
Batteries	2,2€/W		2€/W	20
Converter	0,65€/W		0,65€/W	20

Component costs

- Renewable fraction

The renewable fraction is the fraction of the energy delivered to the load that originated from renewable power sources.

- Maximum annual capacity of shortage

Maximum annual capacity of shortage indicates the percentage of energy demanded that cannot be supplied during a year.

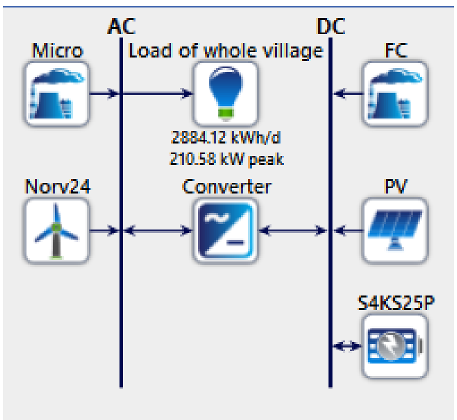
Allowing some capacity shortage can change the results dramatically in some cases. This might happen if a very high peak occurs for a very short time. If the maximum annual capacity shortage is set to zero, HOMER sizes the system to meet even this very high peak load. This could mean that the system has to include large, expensive equipment that is not fully used most of the time. If you allow a small amount of capacity shortage, HOMER could choose to install smaller, less expensive equipment that would be able to supply all but that peak load.

- Operating reserve

Operating reserve is surplus operating capacity that can instantly respond to a sudden increase in the electric load or a sudden decrease in the renewable power output. Operating reserve provides a safety margin that helps ensure reliable electricity supply despite variability in the electric load and the renewable power supply.

3.5.3 Data introduced in homer

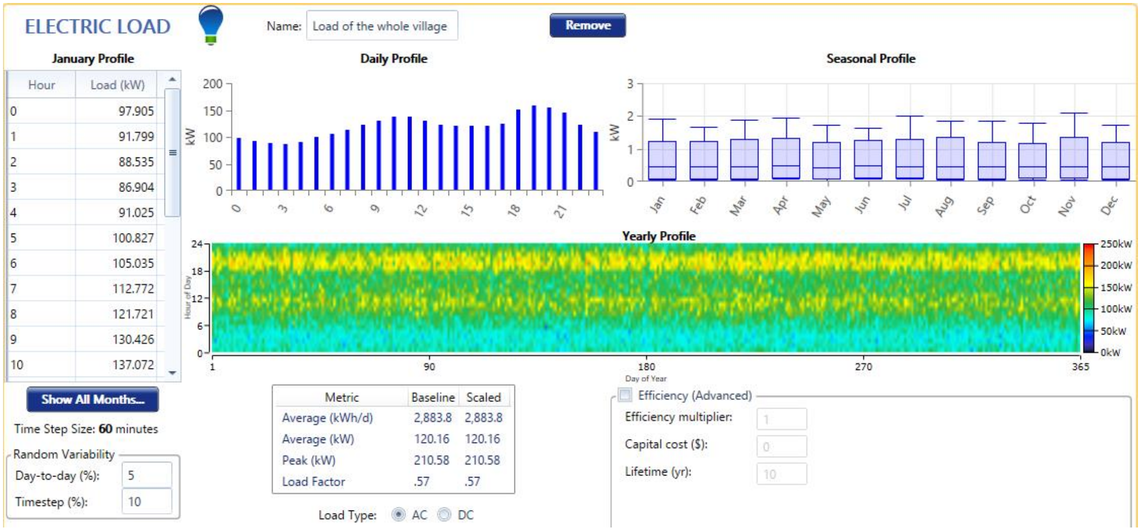
First a schematic of the system with the components to be optimized will be shown.



System representation

3.5.3.1 DEMAND DATA

In this study, the same daily profile has been considered for the whole year, so it is sufficient to introduce the hourly charges taking into account 5% of day-to-day variability and 10% between hours. The window results as shown in the following figure:



Load of the whole village

3.5.3.2 EQUIPMENT

The data of the equipment to be inserted correspond to the wind turbine, the photovoltaic system, the batteries, the fuel cells, micro gas turbine and the converter.

- Photovoltaic system

Apart from the installed power there are several parameters to be determined as:

  - Derating factor is recommended 90%

The photovoltaic (PV) derating factor is a scaling factor that HOMER applies to the PV array power output to account for reduced output in real-world operating conditions compared to the conditions under which the PV panel was rated.

  - Slope, we use our latitude. (43)

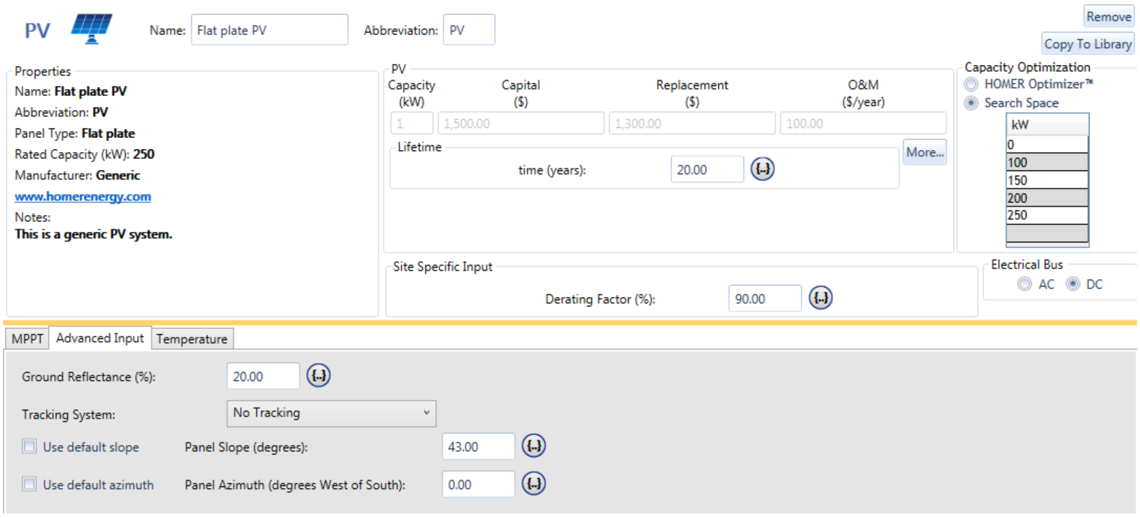
The photovoltaic (PV) slope is the angle at which the panels are mounted relative to horizontal. A slope of 0° corresponds to horizontal, and 90° corresponds to vertical. With fixed-slope systems, a slope roughly equal to the latitude typically maximizes the annual PV energy production. The azimuth specifies the direction towards which the panels slope.

  - Azimuth, 0º North hemisphere, 180º South hemisphere

The azimuth specifies the direction towards which the panels slope.

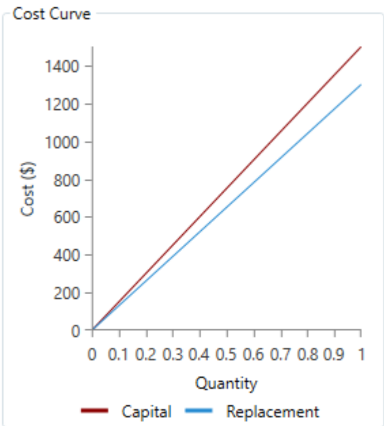
- Ground reflectance

The ground reflectance (also called albedo) is the fraction of solar radiation incident on the ground that is reflected. A typical value for grass-covered areas is 20%. Snow-covered areas may have a reflectance as high as 70%. This value is used in calculating the radiation incident on the tilted PV panels, but it has only a modest effect.



Photovoltaic Panels Characteristics

In addition, the initial cost and replacement cost curve can be obtained.



Investment and replacement curve

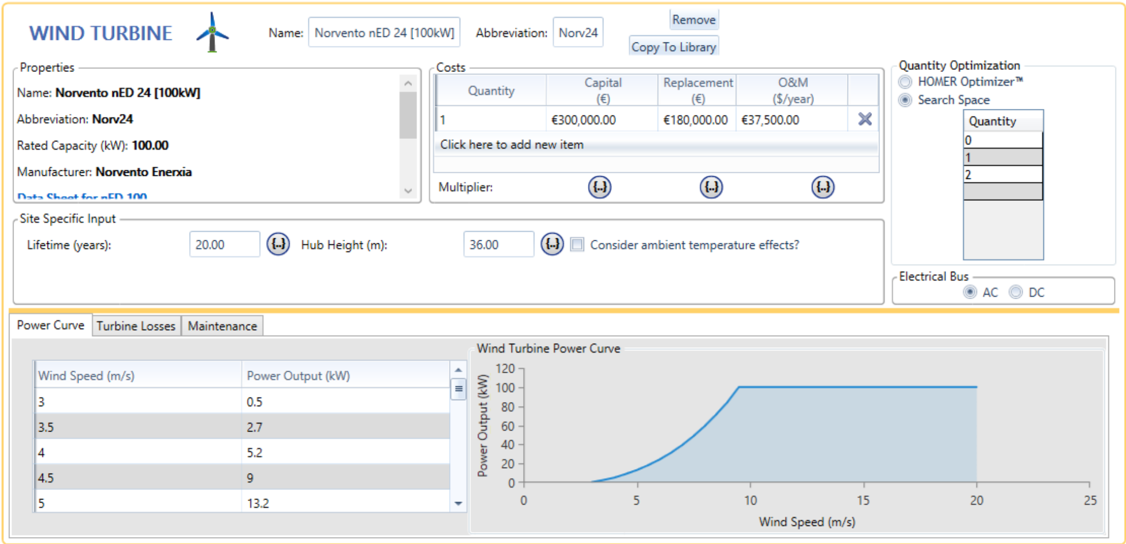
- Wind turbine

In this case, we use a wind turbine whose operating characteristics are provided by the software and we apply the initial, maintenance and replacement prices that we have previously seen.

This wind turbine has been selected among those in the HOMER catalogue taking into account its power curve to obtain maximum performance according to the wind speed existing in the village.

In this case, we use a wind turbine whose operating characteristics are provided by the software and we apply the initial, maintenance and replacement prices that we have previously seen.

This wind turbine has been selected among those in the HOMER catalogue taking into account its power curve to obtain maximum performance according to the wind speed existing in the village.

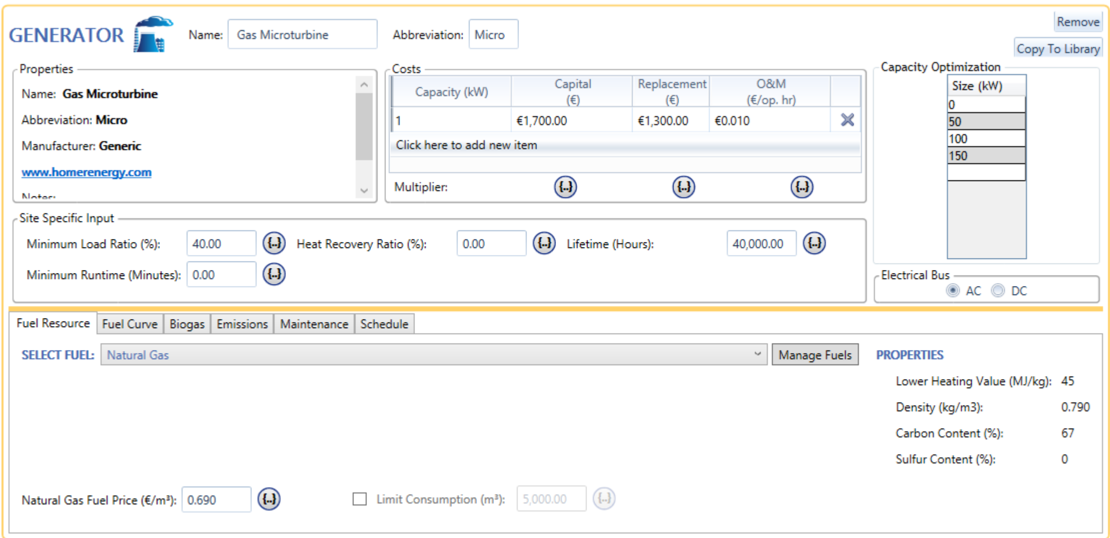


Wind turbines characteristics

- Micro gas turbines

In this case we use a generic one in which all prices are given.

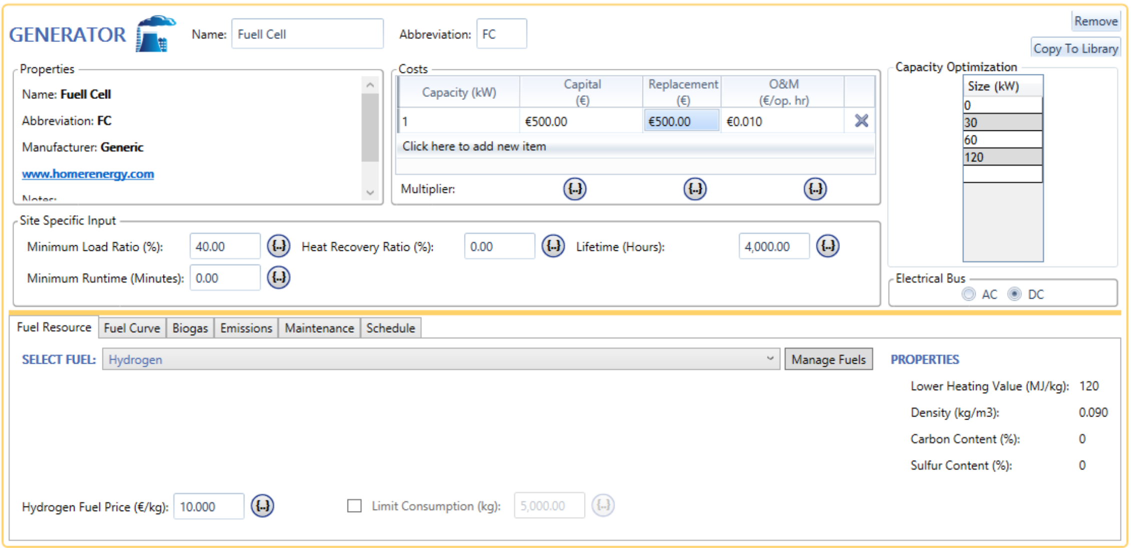
We introduce the different powers, the fuel needed, natural gas, and its price which establishes the market today, in addition to establishing a minimum load ratio of 40%.



Micro gas turbine characteristics

- Fuel cells

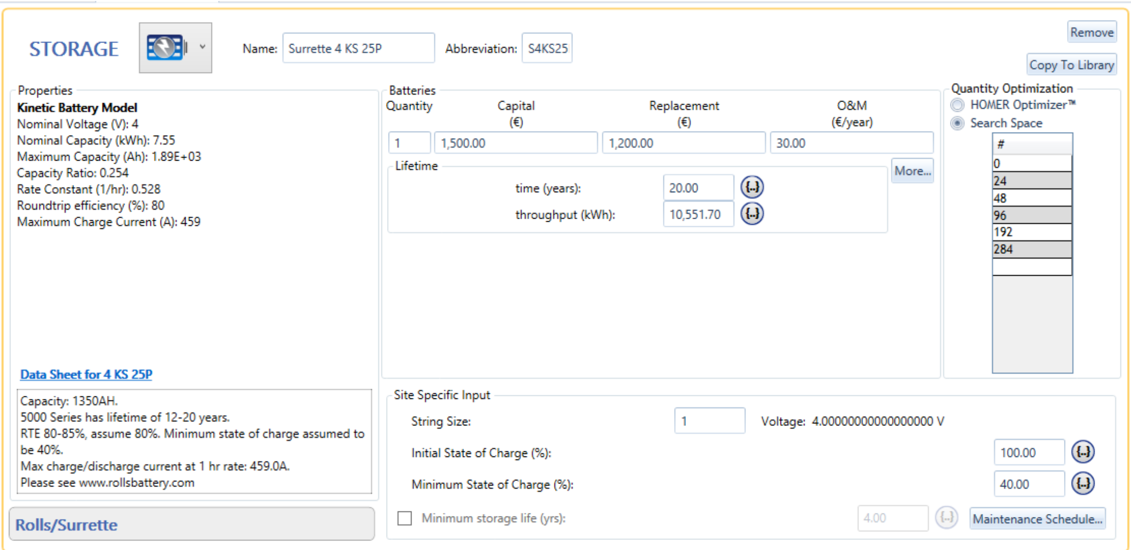
We use fuel cells powered by hydrogen whose market price is around 10 € / kg. The price of the installed kW has been searched in the data of a real project and we establish the Minimum Load Ratio at 40%.



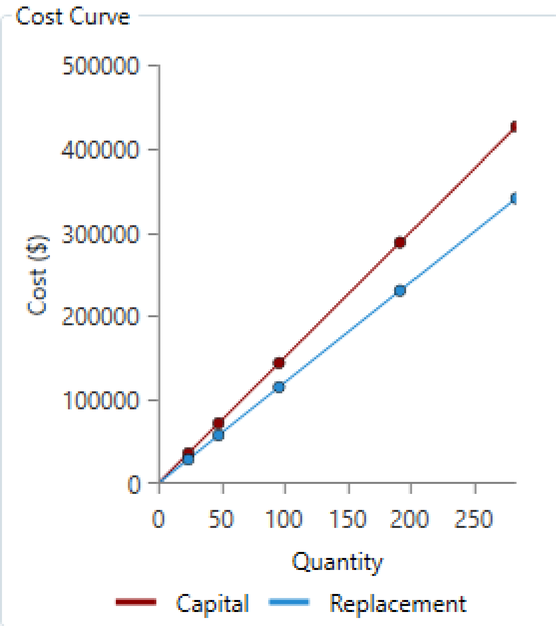
Micro gas turbine characteristics

- Batteries

We use an existing type of battery in the catalogue, we only establish the price according to the data provided previously and we select a 40% minimum load status. Also we introduce some reference numbers of quantity of batteries.



Batteries characteristics

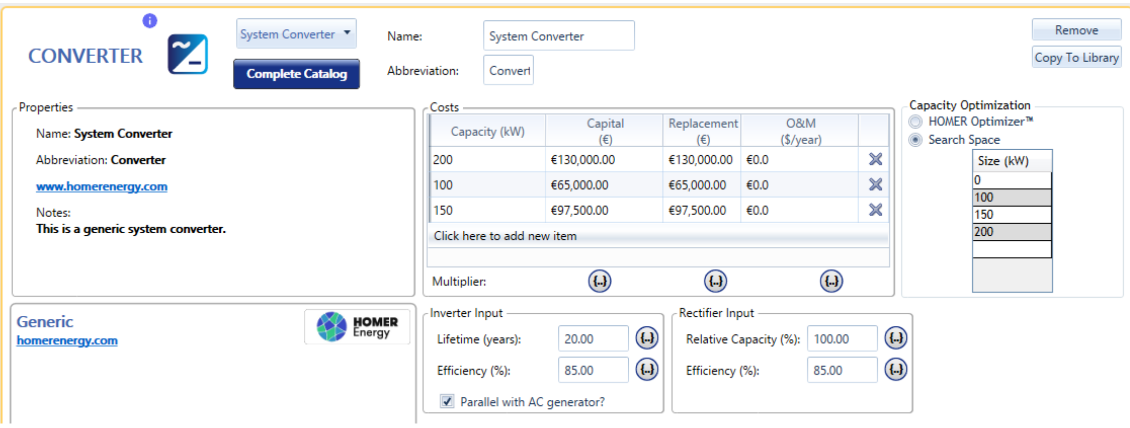


Batteries cost curve

- Converter

There is only one type of converter in the catalogue, so we select different powers and calculate the price according to the data provided above.

We also introduce a conservative efficiency of 80%



Converter characteristics

3.5.4 Results

Considering all the equipment described above with its different powers and sizes, in addition to the different resources, the system simulation has been carried out.

We use as an example the case in which the minimum renewable factor is 0% and shortage capacity 0%.

Architecture						Cost				System		FC		
PV (kW)	Norv24	FC (kW)	Micro (kW)	S4KS25P	Converter (kW)	Dispatch	COE (€)	NPC (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (kg)
150	1		100	192	100	CC	€0.304	€3.70M	€229,425	€1.05M	41.8	209,721			
200	1	30.0	150	24	150	CC	€0.313	€3.81M	€242,369	€1.00M	45.6	210,681	52.0	1,259	264
	2		150	24	50.0	CC	€0.315	€3.84M	€251,700	€923,500	46.2	206,730			
	2	30.0	150	48	50.0	CC	€0.317	€3.86M	€249,408	€974,500	46.2	204,018	16.0	475	99.8
250			150	24	150	CC	€0.319	€3.89M	€269,606	€763,500	24.7	285,120			
250		30.0	150	48	150	CC	€0.326	€3.97M	€272,780	€814,500	24.7	283,080	103	2,965	623

Optimization results

We can see that the configurations with lower net present cost (NPC) are composed by:

1) Photovoltaic panels (150kW), one wind generator, micro gas turbine of 100 kW, 192 batteries S4KS25P, converter of 100 kW

2) Photovoltaic panels (200 kW), fuel cells (30kW), micro gas turbine of 150 kW, 24 batteries S4KS25P, converter of 150 kW

3) Two wind generators, micro gas turbine of 150 kW, 24 batteries S4KS25P, converter of 50 kW

We can conclude that there are three common elements, micro gas turbines, batteries and converter. Although these vary in their number and power.

3.5.4.1 ANALYSIS OF RESULTS

- Economic analysis

The most optimal economic system has the following features:

- Levelized cost of energy (COE) 0.34€. It is the average cost per kWh of useful electrical energy produced by the system.

- Net present cost (NPC) 3.7M€. It is the present value of all the costs of installing and operating the component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime.

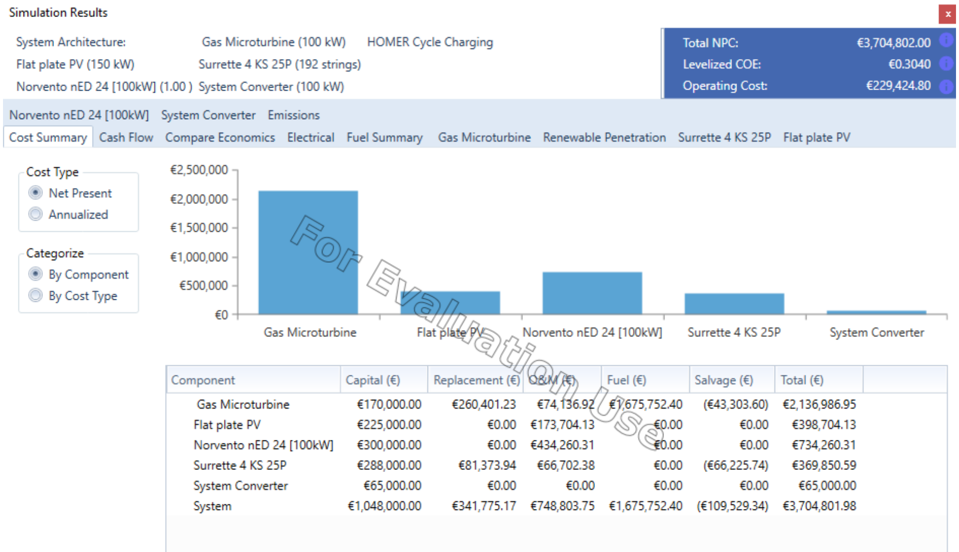
- Operating cost 229425 €/yr. It is the annualized value of all costs and revenues other than initial capital costs.

- Initial capital 1.05M€

- Renewable fraction (41.8%) is the fraction of the energy delivered to the load that originated from renewable power sources

- Total fuel 209721 L/yr

In the tab of economic costs, the graph of the investments by components and the breakdown of their costs is shown. For this system it is observed that the biggest costs correspond to the gas microturbine. Although the initial investment of the wind turbine is greater, the total cost of the microturbine at the end of the useful life of the installation is higher due to replacement, fuel and maintenance costs.



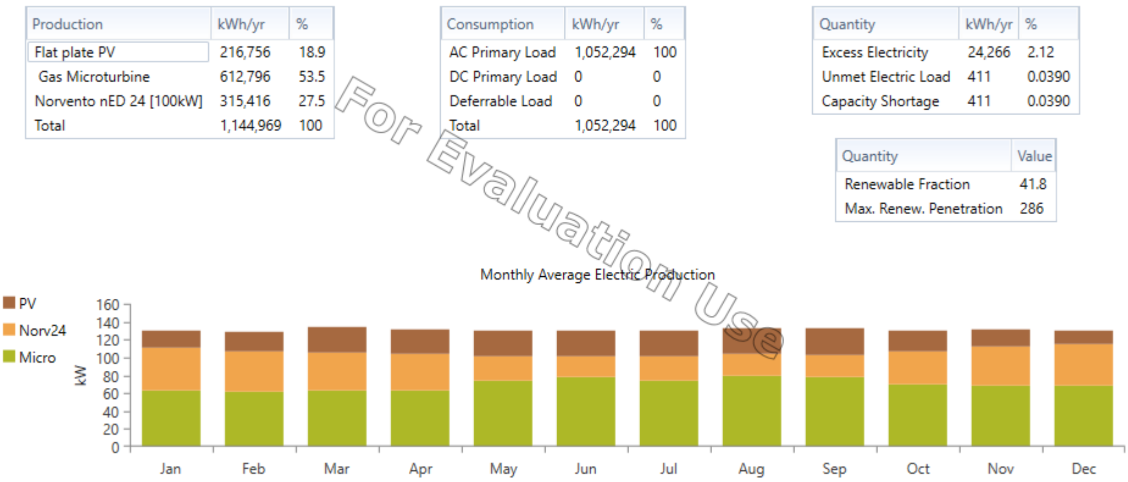
Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Gas Microturbine	€170,000.00	€260,401.23	€74,136.92	€1,675,752.40	(€43,303.60)	€2,136,986.95
Flat plate PV	€225,000.00	€0.00	€173,704.13	€0.00	€0.00	€398,704.13
Norvento nED 24 [100kW]	€300,000.00	€0.00	€434,260.31	€0.00	€0.00	€734,260.31
Surrette 4 KS 25P	€288,000.00	€81,373.94	€66,702.38	€0.00	(€66,225.74)	€369,850.59
System Converter	€65,000.00	€0.00	€0.00	€0.00	€0.00	€65,000.00
System	€1,048,000.00	€341,775.17	€748,803.75	€1,675,752.40	(€109,529.34)	€3,704,801.98

Configuration costs

- Electrical production

The software also provides information on the energy production of the system. It is observed that approximately 55% of the energy comes from the microturbines ,28% from the wind turbine and 19% from photovoltaic panels.

It can also be seen that there is only 2% excess energy. It translates into a loss of capital invested.



Production	kWh/yr	%
Flat plate PV	216,756	18.9
Gas Microturbine	612,796	53.5
Norvento nED 24 [100kW]	315,416	27.5
Total	1,144,969	100

Consumption	kWh/yr	%
AC Primary Load	1,052,294	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	1,052,294	100

Quantity	kWh/yr	%
Excess Electricity	24,266	2.12
Unmet Electric Load	411	0.0390
Capacity Shortage	411	0.0390

Quantity	Value
Renewable Fraction	41.8
Max. Renew. Penetration	286

Electrical production

Next we will show tables of results using different values of renewable factor and shortage capacity.

Table of economic costs:

Min RF (%)	Shortage capacity (%)	Photvoltaic (kW)	Wind turbine (nº)	Fuel cell (kW)	Microturbine (kW)	Nº batteries	Converter (kW)	COE (€)	NPC (M€)	OC (k€/yr)	IC (M€)	RF (%)
0	0	150	1	0	100	192	100	0,34	3,7	229,4	1,05	41,8
50	0	100	2	0	150	24	100	0,32	3,902	241,5	1,106	53,1
60	0	150	2	0	100	284	100	0,33	3,998	217	1,486	60,6
70	0	250	2	30	150	192	150	0,33	4,071	210,7	1,631	71,64
0	2	100	1	0	100	48	100	0,29	3,51	237,5	0,757	37,7
50	2	100	2	0	100	24	100	0,31	3,66	227,7	1,02	53,1
60	2	100	2	0	100	192	50	0,31	3,68	210,5	1,24	62,7
70	2	250	2	30	150	192	150	0,33	3,7	210,7	1,63	71,64

When I increased the renewable factor to 70%, I obtained a solution that according to the software was not feasible.

It can be seen that in the situation in which the microgrid feeds 100% of the demand.

The higher the renewable factor, the higher the net present cost and the higher the initial capital. But the cost of the kWh is reduced if we put a minimum percentage of renewable factor.

In addition, it is verified that applying only a shortage capacity of 2% greatly reduces all types of costs.

Table of percentage of production of each energy source:

RF (%)	SC (%)	Production %			
		Photvoltaic	Wind turbine	Fuel cell	Microturbine
0	0	18,9	27,5	0	53,5
50	0	11,4	49,7	0	39,8
60	0	17,2	50	0	32,8
70	0	28	48,9	0,1	23
0	2	13,1	28,6	0	58,3
50	2	11,5	50,1	0	38,4
60	2	12,5	54,4	0	33,2
70	2	28	48,9	0,1	23

We can see that according to the price of the energy sources and weather conditions in the village. The most used sources to produce energy are microturbines and wind turbines. After the photovoltaic panels and almost unused fuel cells.

4. CONCLUSIONS

First of all, we were able to calculate a low voltage overhead line. Meeting the different electrical requirements such as maximum permissible current for the conductors, voltage drop from each transformation centre to supports end of line, protection of the conductors...

In addition to this, mechanical calculation of the different types of supports was also carried out, considering the maximum admissible tension, in the most critical situations in the situation in which the line is located.

In the same way, electrical calculations have been made for middle voltage line. As obviously the tension is greater and naked conductors are used. It is necessary to be more careful with the safety distances with respect to roads, rivers, buildings, ... and the cables themselves.

In addition, safety calculations have been carried out on the cables to avoid their breakage, for example, taking into account the EDS and CHS according to Zone A.

In the mechanical calculation of supports in this case several hypotheses of security have to be taken into account.

Throughout the project the characteristics of the area have been determined, and the energy needs of the population and the milking parlour have been evaluated.

Through the study of a real area, the importance of analysing the potential of renewable energies has been shown, prior to the proposal of solutions that conclude with the determination of a possible energy mix.

In this way, the potential of the photovoltaic solar and wind resource in the area was determined through the NASA database in order to later dimension the wind turbines and solar panels that make up the design of the microgrid.

Once this has been achieved, the hybrid system has been sized to achieve a techno-economic commitment and optimization of the system. For this the corresponding simulations have been carried out to compare the results and obtain more precision in the sizing. The configuration that fulfils the commitment of the lowest investment, has turned out to be a system composed of a photovoltaic subsystem of 150 kW, a wind subsystem of 100 kW, a subsystem of storage of batteries of 192 units and a support system with a microturbine of 100 kW. But the cost of kWh is more expensive, than in other solutions that use more renewable energy but with more initial investment.

It can be seen that in only two cases the hydrogen cells are used, this may be due to the high price of hydrogen.

The energy cost of this hybrid isolated system is 0.34€ / kWh, while the current value in Spain is almost 0.12€ / kWh. Although the cost of energy increases considerably, the growing installation of renewable energy sources is a fact. Since it is necessary due to the problems of consumption, increase in the price of oil and globalized pollution

Thanks to continuous research and experience, renewable energies are becoming cheaper and more competitive with fossil fuels. But there is still a long way to go until its use becomes a majority.

5. ANNEXES

ANNEX 1

Tables of mechanical calculation Low voltage cables. Zone A [27]

RZ-0,6/1kV 3x25 Al + 54,6 Alm

TABLA DE TENDIDO (Flechas y tensiones) - ZONA A (Altitud de 0 a 500 m)

TENSE FLOJO

T = Tracción en daN — Tracción máxima, daN = **500** — Conductor: **RZ 0,6/1kV 3x25Al/54,6alm**

F = Flecha en m — Carga rotura, daN = **1.660** — Diámetro, mm = **24,00** — Coef.dilatación/°C= **0,000023** — Peso + Viento, daN/m = **1,312**

Coeficiente de Seguridad mínimo = **3,32** — Peso, daN/m = **0,530** — M.Elast.,daN/mm2= **6.200** — Peso + Viento/3, daN/m = **0,664**

Vano de	TENSIONES Y FLECHAS MAXIMAS										FLECHA MÍNIMA		Parámetro Catenaria		Tabla de tendido Temperatura en °C																Vano de
Regu-	15 °C+V		0°C+ V/3		50 °C		T. Máx		F. Máx		0 °C		Flecha		40 °C		30 °C		25 °C		20 °C		15 °C		EDS	10 °C		5 °C		Regu-
lación	T	F	T	F	T	F	T	C.S.	T	F	T	F	Máx.	Mín	T	F	T	F	T	F	T	F	T	F	%	T	F	T	F	lación
m	daN	m	daN	m	daN	m	daN		daN	m	daN	m			daN	m	daN	m	daN	m	daN	m	daN	m	Cr.	daN	m	daN	m	m
20	427	0,15	500	0,07	161	0,16	500	3,32	161	0,16	496	0,05	305	937	213	0,12	277	0,10	312	0,08	347	0,08	384	0,07	23,13	421	0,06	459	0,06	20
25	444	0,23	500	0,10	175	0,24	500	3,32	175	0,24	495	0,08	331	934	223	0,19	282	0,15	315	0,13	349	0,12	384	0,11	23,16	421	0,10	457	0,09	25
30	463	0,32	500	0,15	189	0,32	500	3,32	463	0,32	492	0,12	353	929	232	0,26	287	0,21	318	0,19	351	0,17	385	0,15	23,19	420	0,14	456	0,13	30
35	481	0,42	500	0,20	201	0,40	500	3,32	481	0,42	490	0,17	367	925	241	0,34	293	0,28	322	0,25	353	0,23	385	0,21	23,22	419	0,19	454	0,18	35
40	499	0,53	500	0,27	212	0,50	500	3,32	499	0,53	487	0,22	381	919	250	0,42	298	0,36	325	0,33	355	0,30	386	0,27	23,25	419	0,25	452	0,23	40
45	500	0,66	476	0,35	211	0,64	500	3,32	500	0,66	458	0,29	381	865	244	0,55	285	0,47	309	0,43	336	0,40	364	0,37	21,92	394	0,34	426	0,32	45
50	500	0,82	451	0,46	210	0,79	500	3,32	500	0,82	428	0,39	381	808	238	0,70	273	0,61	294	0,56	317	0,52	342	0,48	20,60	369	0,45	398	0,42	50
55	500	0,99	426	0,59	209	0,96	500	3,32	500	0,99	399	0,50	381	752	233	0,86	263	0,76	281	0,71	300	0,67	322	0,62	19,39	346	0,58	371	0,54	55
60	500	1,18	404	0,74	208	1,15	500	3,32	500	1,18	371	0,64	381	700	229	1,04	254	0,94	269	0,89	286	0,83	304	0,78	18,33	325	0,73	347	0,69	60
65	500	1,39	384	0,91	207	1,35	500	3,32	500	1,39	346	0,81	381	653	225	1,24	247	1,13	260	1,08	274	1,02	289	0,97	17,44	307	0,91	326	0,86	65
70	500	1,61	367	1,11	207	1,57	500	3,32	500	1,61	325	1,00	381	613	222	1,46	241	1,35	252	1,29	264	1,23	277	1,17	16,69	292	1,11	307	1,06	70
75	500	1,85	352	1,33	206	1,81	500	3,32	500	1,85	307	1,21	381	580	220	1,70	236	1,58	246	1,52	256	1,46	267	1,40	16,07	279	1,34	292	1,27	75
80	500	2,10	340	1,56	206	2,06	500	3,32	500	2,10	292	1,45	381	552	218	1,95	232	1,83	240	1,77	249	1,70	258	1,64	15,56	269	1,58	280	1,51	80
85	500	2,37	329	1,82	205	2,33	500	3,32	500	2,37	280	1,71	381	529	216	2,22	229	2,09	236	2,03	243	1,97	251	1,90	15,14	260	1,84	270	1,77	85
90	500	2,66	321	2,10	205	2,62	500	3,32	500	2,66	270	1,99	381	510	215	2,50	226	2,38	232	2,31	238	2,25	246	2,19	14,79	253	2,12	261	2,05	90
95	500	2,96	313	2,4	205	2,92	500	3,32	500	3,0	262	2,3	381	494	213	2,8	223	2,68	229	2,62	235	2,6	241	2,5	14,50	247	2,42	254	2,35	95
100	500	3,28	307	2,7	204	3,24	500	3,32	500	3,3	255	2,6	381	481	212	3,1	221	3,00	226	2,93	231	2,9	237	2,8	14,25	242	2,74	248	2,67	100

RZ-0,6/1kV 3x50 Al + 54,6 Alm

TABLA DE TENDIDO (Flechas y tensiones) - ZONA A (Altitud de 0 a 500 m)

TENSE FLOJO

T = Tracción en daN — Tracción máxima, daN = **500** — Conductor: **RZ 0,6/1kV 3x50Al/54,6 alm**

F = Flecha en m — Carga rotura, daN = **1.660** — Diámetro, mm = **30,750** — Coef.dilatación/°C= **0,000023** — Peso + Viento, daN/m = **1,713**

Coeficiente de Seguridad mínimo = **3,32** — Peso, daN/m = **0,755** — M.Elast.,daN/mm2= **6.200** — Peso + Viento/3, daN/m = **0,913**

Vano de	TENSIONES Y FLECHAS MAXIMAS										FLECHA MÍNIMA		Parámetro Catenaria		Tabla de tendido Temperatura en °C																Vano de
Regu-	15 °C+V		0°C+ V/3		50 °C		T. Máx		F. Máx		0 °C		Flecha		40 °C		30 °C		25 °C		20 °C		15 °C		EDS	10 °C		5 °C		Regu-
lación	T	F	T	F	T	F	T	C.S.	T	F	T	F	Máx.	Mín	T	F	T	F	T	F	T	F	T	F	%	T	F	T	F	lación
m	daN	m	daN	m	daN	m	daN		daN	m	daN	m			daN	m	daN	m	daN	m	daN	m	daN	m	Cr.	daN	m	daN	m	m
20	447	0,19	500	0,09	185	0,20	500	3,32	185	0,20	494	0,08	246	654	230	0,16	287	0,13	318	0,12	352	0,11	386	0,10	23,25	421	0,09	458	0,08	20
25	471	0,28	500	0,14	203	0,29	500	3,32	203	0,29	491	0,12	269	651	244	0,24	295	0,20	324	0,18	355	0,17	387	0,15	23,33	421	0,14	456	0,13	25
30	494	0,39	500	0,21	219	0,39	500	3,32	494	0,39	488	0,17	288	646	256	0,33	303	0,28	330	0,26	358	0,24	389	0,22	23,42	421	0,20	454	0,19	30
35	500	0,52	477	0,29	223	0,52	500	3,32	500	0,52	460	0,25	292	610	255	0,45	294	0,39	317	0,36	342	0,34	369	0,31	22,25	398	0,29	429	0,27	35
40	500	0,69	446	0,41	223	0,68	500	3,32	500	0,69	424	0,36	292	561	249	0,61	281	0,54	300	0,50	321	0,47	344	0,44	20,72	369	0,41	395	0,38	40
45	500	0,87	418	0,55	222	0,86	500	3,32	500	0,87	389	0,49	292	515	244	0,78	271	0,71	286	0,67	303	0,63	322	0,59	19,40	343	0,56	365	0,52	45
50	500	1,07	393	0,73	222	1,06	500	3,32	500	1,07	359	0,66	292	475	240	0,98	262	0,90	275	0,86	289	0,82	304	0,78	18,31	321	0,74	339	0,70	50
55	500	1,30	372	0,93	222	1,29	500	3,32	500	1,30	334	0,86	292	442	237	1,20	255	1,12	266	1,07	277	1,03	290	0,99	17,44	303	0,94	318	0,90	55
60	500	1,54	356	1,16	222	1,54	500	3,32	500	1,54	314	1,08	292	416	235	1,45	250	1,36	259	1,31	268	1,27	278	1,22	16,76	289	1,18	301	1,13	60
65	500	1,81	342	1,41	221	1,80	500	3,32	500	1,81	299	1,34	292	395	233	1,71	246	1,62	253	1,58	261	1,53	269	1,48	16,22	278	1,43	288	1,39	65
70	500	2,10	331	1,69	221	2,09	500	3,32	500	2,10	286	1,62	292	379	231	2,00	243	1,91	249	1,86	255	1,81	262	1,77	15,80	270	1,72	278	1,67	70
75	500	2,41	322	1,99	221	2,40	500	3,32	500	2,41	277	1,92	292	366	230	2,31	240	2,22	245	2,17	251	2,12	257	2,07	15,46	263	2,02	270	1,97	75
80	500	2,75	315	2,32	221	2,74	500	3,32	500	2,75	269	2,25	292	356	229	2,64	237	2,55	242	2,50	247	2,45	252	2,40	15,18	257	2,35	263	2,30	80
85	500	3,10	309	2,67	221	3,09	500	3,32	500	3,10	263	2,60	292	348	228	3,00	236	2,90	240	2,85	244	2,80	248	2,75	14,95	253	2,70	258	2,65	85
90	500	3,48	304	3,04	221	3,47	500	3,32	500	3,48	258	2,97	292	341	227	3,37	234	3,28	237	3,23	241	3,18	245	3,13	14,76	249	3,08	253	3,02	90
95	500	3,87	300	3,4	221	3,87	500	3,32	500	3,9	253	3,4	292	336	227	3,8	233	3,67	236	3,62	239	3,6	242	3,5	14,60	246	3,47	250	3,42	95
100	500	4,29	297	3,9	221	4,28	500	3,32	500	4,3	250	3,8	292	331	226	4,2	231	4,09	234	4,04	237	4,0	240	3,9	14,47	243	3,89	247	3,84	100

RZ-0,6/1kV 3x95 Al + 54,6 Alm

TABLA DE TENDIDO (Flechas y tensiones) - ZONA A (Altitud de 0 a 500 m)

TENSE FLOJO

T = Tracción en daN — Tracción máxima, daN = **500** — Conductor: **RZ 0,6/1kV 3x95Al/54,6 alm**

F = Flecha en m — Carga rotura, daN = **1.660** — Diámetro, mm = **40,25** — Coef.dilatación/°C= **0,000023** — Peso + Viento, daN/m = **2,362**

Coeficiente de Seguridad mínimo = **3,32** — Peso, daN/m = **1,236** — M.Elast.,daN/mm2= **6.200** — Peso + Viento/3, daN/m = **1,406**

Vano de Regulación	TENSIONES Y FLECHAS MAXIMAS										FLECHA MÍNIMA		Parámetro Catenaria		Tabla de tendido Temperatura en °C																Vano de Regulación
	15 °C+V		0°C+ V/3		50 °C		T. Máx		F. Máx		0 °C		Flecha		40 °C		30 °C		25 °C		20 °C		15 °C		EDS	10 °C		5 °C		
m	T daN	F m	T daN	F m	T daN	F m	T daN	C.S.	T daN	F m	T daN	F m	Máx.	Mín	T daN	F m	T daN	F m	T daN	F m	T daN	F m	T daN	F m	% Cr.	T daN	F m	T daN	F m	m
20	477	0,25	500	0,14	230	0,27	500	3,32	230	0,27	491	0,13	186	397	266	0,23	311	0,20	337	0,18	365	0,17	394	0,16	23,74	425	0,15	458	0,14	20
25	500	0,37	492	0,22	249	0,39	500	3,32	249	0,39	479	0,20	201	387	280	0,34	319	0,30	341	0,28	365	0,26	391	0,25	23,57	419	0,23	448	0,22	25
30	500	0,53	455	0,35	251	0,55	500	3,32	251	0,55	436	0,32	203	352	276	0,50	306	0,45	324	0,43	343	0,41	364	0,38	21,90	386	0,36	410	0,34	30
35	500	0,72	423	0,51	253	0,75	500	3,32	253	0,75	398	0,48	205	322	273	0,69	297	0,64	310	0,61	325	0,58	341	0,55	20,56	359	0,53	378	0,50	35
40	500	0,95	397	0,71	255	0,97	500	3,32	255	0,97	368	0,67	206	298	271	0,91	290	0,85	300	0,82	312	0,79	324	0,76	19,54	338	0,73	352	0,70	40
45	500	1,20	377	0,94	256	1,22	500	3,32	256	1,22	345	0,91	207	279	269	1,16	285	1,10	293	1,07	302	1,04	312	1,00	18,78	322	0,97	333	0,94	45
50	500	1,48	362	1,21	257	1,51	500	3,32	257	1,51	329	1,18	208	266	268	1,44	281	1,38	287	1,35	295	1,31	302	1,28	18,22	311	1,24	319	1,21	50
55	500	1,79	351	1,52	258	1,82	500	3,32	258	1,82	316	1,48	208	256	267	1,75	278	1,69	283	1,65	289	1,62	295	1,58	17,79	302	1,55	309	1,51	55
60	500	2,13	342	1,85	258	2,16	500	3,32	258	2,16	307	1,81	209	248	266	2,09	275	2,02	280	1,99	285	1,96	290	1,92	17,47	295	1,89	301	1,85	60
65	500	2,50	335	2,22	259	2,53	500	3,32	259	2,53	300	2,18	209	243	266	2,46	273	2,39	277	2,36	281	2,32	286	2,29	17,21	290	2,25	295	2,22	65
70	500	2,90	330	2,61	259	2,93	500	3,32	259	2,93	294	2,58	210	238	265	2,86	272	2,79	275	2,76	279	2,72	282	2,69	17,01	286	2,65	290	2,61	70
75	500	3,33	326	3,04	259	3,36	500	3,32	259	3,36	290	3,00	210	234	265	3,29	270	3,22	273	3,19	277	3,15	280	3,11	16,85	283	3,08	286	3,04	75
80	500	3,79	322	3,50	260	3,82	500	3,32	260	3,82	286	3,46	210	232	264	3,75	269	3,68	272	3,65	275	3,61	277	3,57	16,72	280	3,54	283	3,50	80
85	500	4,28	319	3,99	260	4,31	500	3,32	260	4,31	283	3,95	210	229	264	4,24	269	4,17	271	4,13	273	4,10	276	4,06	16,61	278	4,03	281	3,99	85
90	500	4,80	317	4,51	260	4,83	500	3,32	260	4,83	281	4,47	210	227	264	4,76	268	4,69	270	4,65	272	4,62	274	4,58	16,51	276	4,54	279	4,51	90
95	500	5,35	315	5,1	260	5,38	500	3,32	260	5,4	279	5,0	210	226	264	5,3	267	5,24	269	5,20	271	5,2	273	5,1	16,44	275	5,09	277	5,06	95
100	500	5,93	313	5,6	260	5,96	500	3,32	260	6,0	277	5,6	211	224	263	5,9	267	5,82	268	5,78	270	5,7	272	5,7	16,37	274	5,67	275	5,64	100

RZ-0,6/1kV 3x150 Al + 80 Alm

TABLA DE TENDIDO (Flechas y tensiones) - ZONA A (Altitud de 0 a 500 m)

TENSE FLOJO

T = Tracción en daN — Tracción máxima, daN = **500** — Conductor: **RZ 0,6/1kV 3x150Al/80 alm**

F = Flecha en m — Carga rotura, daN = **2.000** — Diámetro, mm = **47,750** — Coef.dilatación/°C= **0,000023** — Peso + Viento, daN/m = **2,975**

Coeficiente de Seguridad mínimo = **4,00** — Peso, daN/m = **1,776** — M.Elast.,daN/mm2= **6.200** — Peso + Viento/3, daN/m = **1,946**

Vano de Regulación	TENSIONES Y FLECHAS MAXIMAS										FLECHA MÍNIMA		Parámetro Catenaria		Tabla de tendido Temperatura en °C																Vano de Regulación
	15 °C+V		0°C+ V/3		50 °C		T. Máx		F. Máx		0 °C		Flecha		40 °C		30 °C		25 °C		20 °C		15 °C		EDS	10 °C		5 °C		
m	T daN	F m	T daN	F m	T daN	F m	T daN	C.S.	T daN	F m	T daN	F m	Máx.	Mín	T daN	F m	T daN	F m	T daN	F m	T daN	F m	T daN	F m	% Cr.	T daN	F m	T daN	F m	m
20	498	0,30	500	0,19	244	0,36	500	4,00	244	0,36	485	0,18	137	273	272	0,33	308	0,29	330	0,27	354	0,25	382	0,23	19,11	413	0,21	448	0,20	20
25	500	0,47	453	0,34	257	0,54	500	4,00	257	0,54	432	0,32	145	243	279	0,50	306	0,45	322	0,43	339	0,41	359	0,39	17,94	381	0,36	405	0,34	25
30	500	0,67	417	0,52	267	0,75	500	4,00	267	0,75	393	0,51	150	221	284	0,70	304	0,66	316	0,63	328	0,61	342	0,58	17,11	357	0,56	374	0,53	30
35	500	0,91	394	0,76	273	1,00	500	4,00	273	1,00	367	0,74	154	207	287	0,95	303	0,90	312	0,87	321	0,85	331	0,82	16,56	342	0,80	354	0,77	35
40	500	1,19	378	1,03	278	1,28	500	4,00	278	1,28	350	1,01	157	197	289	1,23	302	1,18	309	1,15	316	1,12	324	1,10	16,19	332	1,07	341	1,04	40
45	500	1,51	367	1,34	282	1,60	500	4,00	282	1,60	339	1,33	159	191	291	1,55	301	1,49	307	1,47	312	1,44	319	1,41	15,93	325	1,38	332	1,36	45
50	500	1,86	359	1,70	284	1,95	500	4,00	284	1,95	331	1,68	160	186	292	1,90	301	1,85	305	1,82	310	1,79	315	1,77	15,74	320	1,74	325	1,71	50
55	500	2,26	353	2,09	287	2,35	500	4,00	287	2,35	325	2,07	161	183	293	2,30	300	2,24	304	2,21	308	2,18	312	2,16	15,60	316	2,13	320	2,10	55
60	500	2,68	349	2,51	288	2,78	500	4,00	288	2,78	321	2,50	162	181	294	2,73	300	2,67	303	2,64	306	2,61	310	2,59	15,49	313	2,56	317	2,53	60
65	500	3,15	346	2,98	290	3,25	500	4,00	290	3,25	317	2,97	163	179	295	3,19	300	3,14	303	3,11	305	3,08	308	3,05	15,41	311	3,02	314	2,99	65
70	500	3,66	343	3,49	291	3,75	500	4,00	291	3,75	314	3,47	164	177	295	3,70	300	3,64	302	3,61	304	3,59	307	3,56	15,34	309	3,53	312	3,50	70
75	500	4,20	341	4,03	292	4,30	500	4,00	292	4,30	312	4,01	164	176	295	4,24	299	4,19	302	4,16	304	4,13	306	4,10	15,29	308	4,07	310	4,04	75
80	500	4,78	339	4,61	292	4,88	500	4,00	292	4,88	311	4,59	165	175	296	4,82	299	4,77	301	4,74	303	4,71	305	4,68	15,24	307	4,65	309	4,62	80
85	500	5,40	338	5,23	293	5,50	500	4,00	293	5,50	309	5,21	165	174	296	5,45	299	5,39	301	5,36	302	5,33	304	5,30	15,20	306	5,27	307	5,24	85
90	500	6,06	337	5,89	294	6,16	500	4,00	294	6,16	308	5,87	165	173	296	6,10	299	6,05	301	6,02	302	5,99	303	5,96	15,17	305	5,93	306	5,90	90
95	500	6,76	336	6,6	294	6,86	500	4,00	294	6,9	307	6,6	166	173	297	6,8	299	6,74	300	6,71	302	6,7	303	6,7	15,15	304	6,63	306	6,60	95
100	500	7,49	335	7,3	294	7,59	500	4,00	294	7,6	306	7,3	166	172	297	7,5	299	7,48	300	7,45	301	7,4	303	7,4	15,13	304	7,36	305	7,33	100

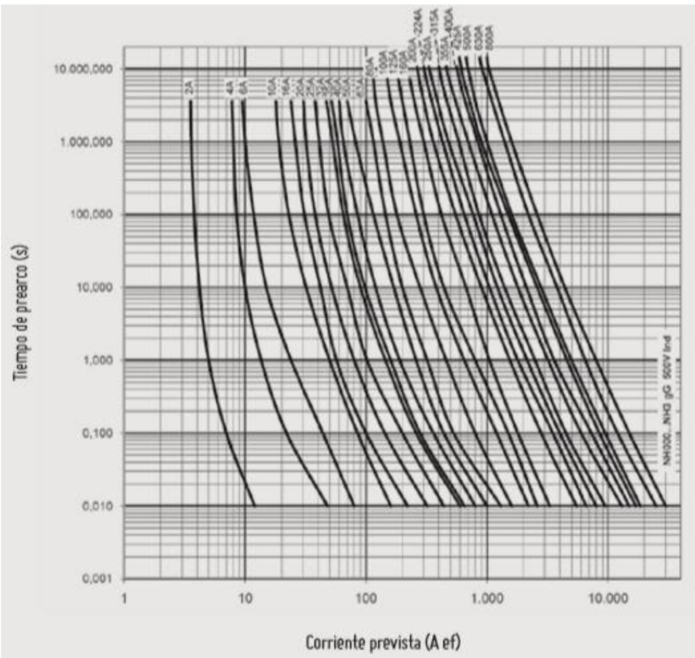
ANNEX 2

Low voltage line fuses characteristics. [df electric manufacturer]

Catalogue

	I_n (A)	REFERENCIA	U (V)	PODER DE CORTE (kA)	EMBALAJE (Ud./CAJA)
NH000	2	381000	500	120	3/90
	4	381005	500	120	3/90
	6	381010	500	120	3/90
	10	381015	500	120	3/90
	16	381020	500	120	3/90
	20	381025	500	120	3/90
	25	381030	500	120	3/90
	32	381035	500	120	3/90
	35	381040	500	120	3/90
	40	381045	500	120	3/90
	50	381050	500	120	3/90
	63	381055	500	120	3/90
	80	381060	500	120	3/90
	100	381065	500	120	3/90
NH00	125	381070	500	120	3/60
	160	381075	500	120	3/60
NH0	6	381110	500	120	3/42
	10	381115	500	120	3/42
	16	381120	500	120	3/42
	20	381125	500	120	3/42
	25	381130	500	120	3/42
	32	381135	500	120	3/42
	35	381140	500	120	3/42
	40	381145	500	120	3/42
	50	381150	500	120	3/42
	63	381155	500	120	3/42
	80	381160	500	120	3/42
	100	381165	500	120	3/42
	125	381170	500	120	3/42
	160	381175	500	120	3/42
NH0 S	200	381180	500	120	3/30
	224	381185	500	120	3/30
	250	381190	500	120	3/30

i-t characteristics



ANNEX 3

Derivation supports calculation.

The scales used in the drawing for calculation of this type of supports are:

- Spans scale 1 cm → 10 m
- Forces scale 1 cm → 100 daN

Graphically we obtain the resultant of the tractions and its perpendicular to which we are going to project half the length of each span.

Using the length of these projections we will calculate the force due to the pressure of the wind.

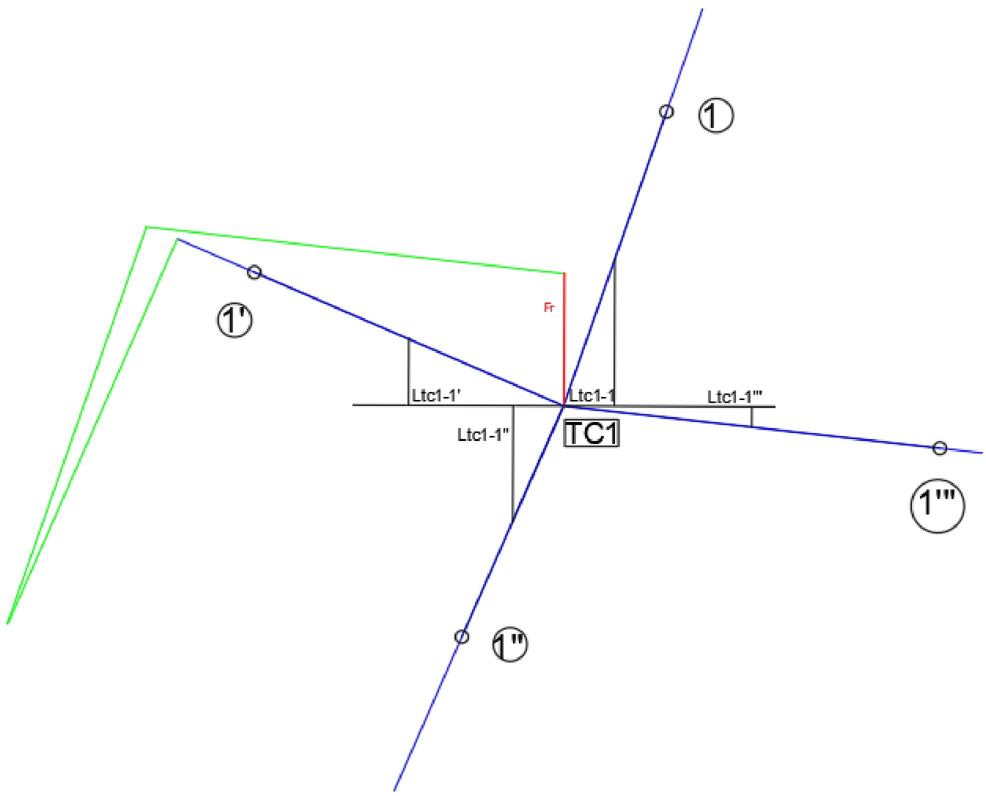
- DERIVATION 1

Derivation 1	Drawing (mm)	Real (m)	Cable
L tc1-1	5,99	5,99	T-95
L tc1-1'	18,39	18,39	T-95
L tc1-1''	6,05	6,05	T-25
L tc1-1'''	22,37	22,37	T-25
	Drawing (mm)	Real (daN)	
Fr	15,72	157,2	
Fv		82,12	
Ft		239,32	
Support		9/400	

$$F_v = p_w \cdot [\emptyset_1 L_{tc1-1} + \emptyset_2 L_{tc1-1'} + \emptyset_3 L_{tc1-1''} + \emptyset_4 L_{tc1-1'''}]$$

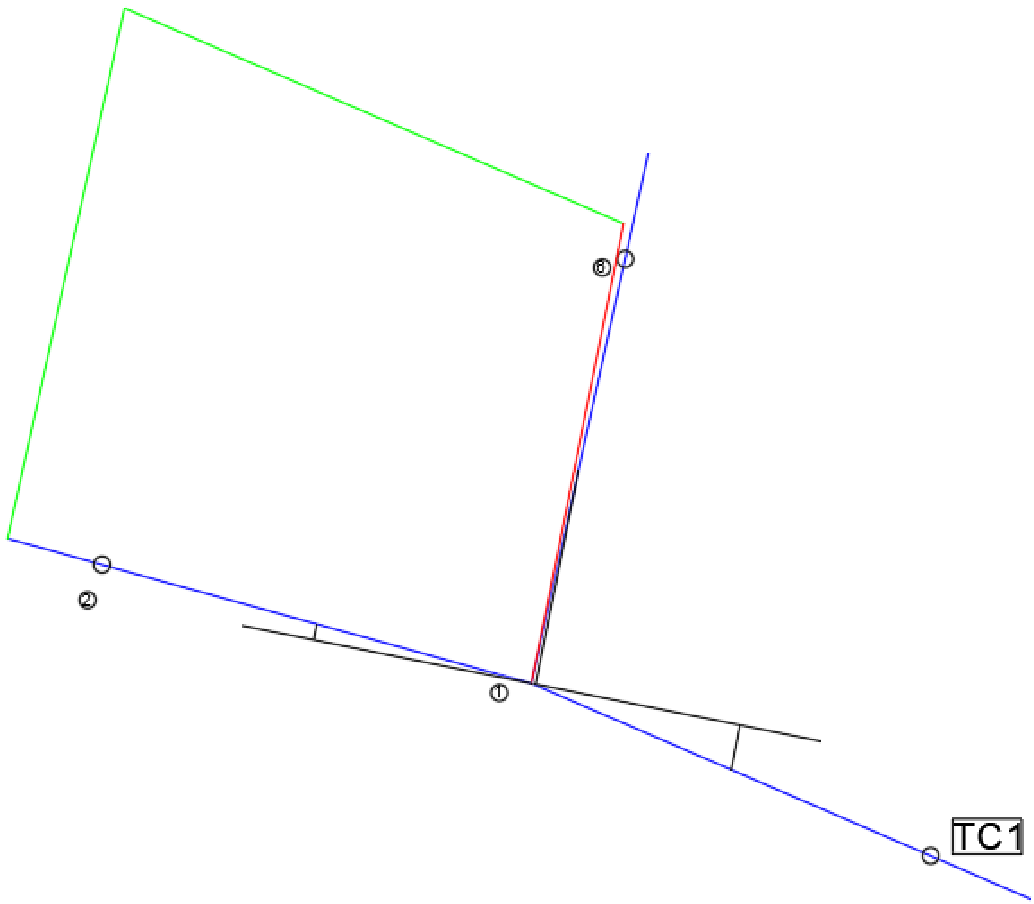
$$F_v = 50 \cdot 10^{-3} \cdot [40.5 \cdot 5.99 + 40.5 \cdot 18.39 + 23.05 \cdot 6.05 + 23.05 \cdot 22.37] = 82.12$$

$$F_T = F_v + F_r = 157.2 + 82.12 = 239.32$$


1
1'
Fr
Ltc1-1'
Ltc1-1
Ltc1-1'''
Ltc1-1''
TC1
1'''
1''

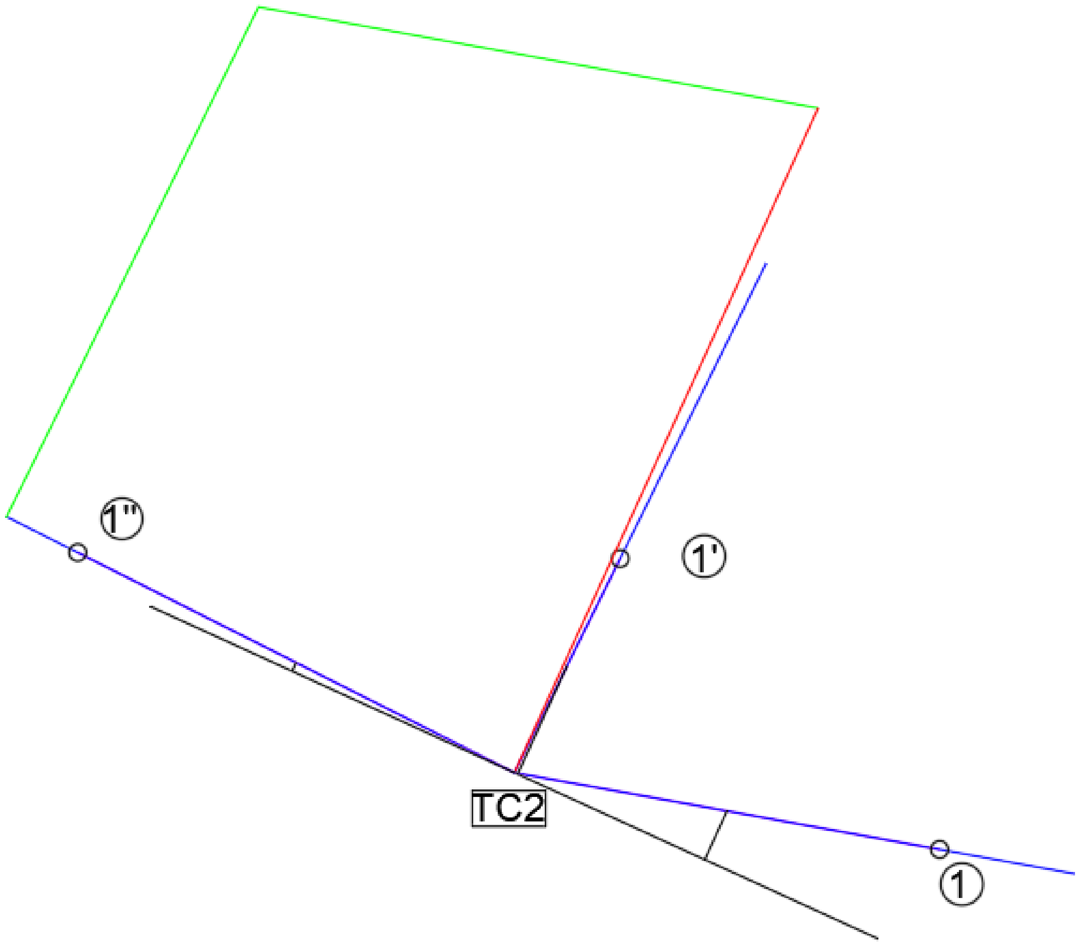
- DERIVATION 2

Derivation 2	Drawing (mm)	Real (m)	Cable
L 1-TC1	19,56	19,56	T-95
L 1-2	20,45	20,45	T-50
L 1-6	0,39	0,39	T-25
	Drawing (mm)	Real (daN)	
Fr	43,16	431,6	
Fv		70,99	
Ft		502,59	
Support		9/630	



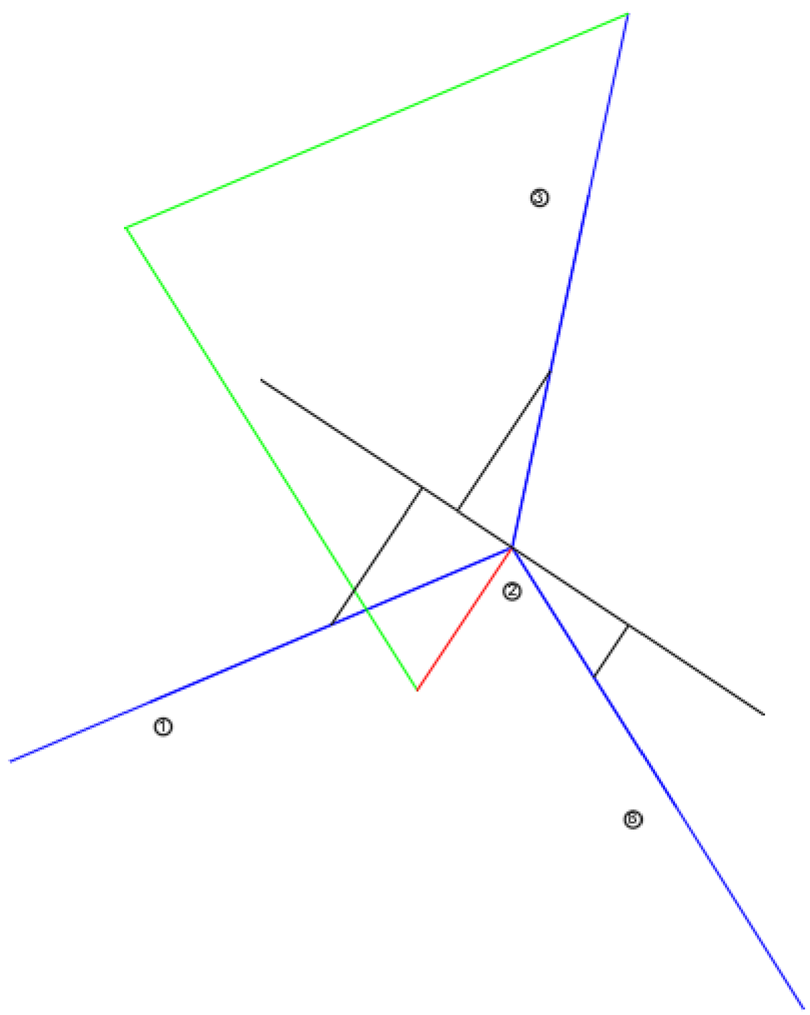
- DERIVATION 3

Derivation 3	Drawing (mm)	Real (m)	Cable
L TC2-1	18,41	18,41	T-95
L TC2-1’	0,32	0,32	T-25
L TC2-1’’	21,48	21,48	T-95
	Drawing (mm)	Real (daN)	
Fr	64,26	642,6	
Fv		81,15	
Ft		723,75	
Support		9/850	



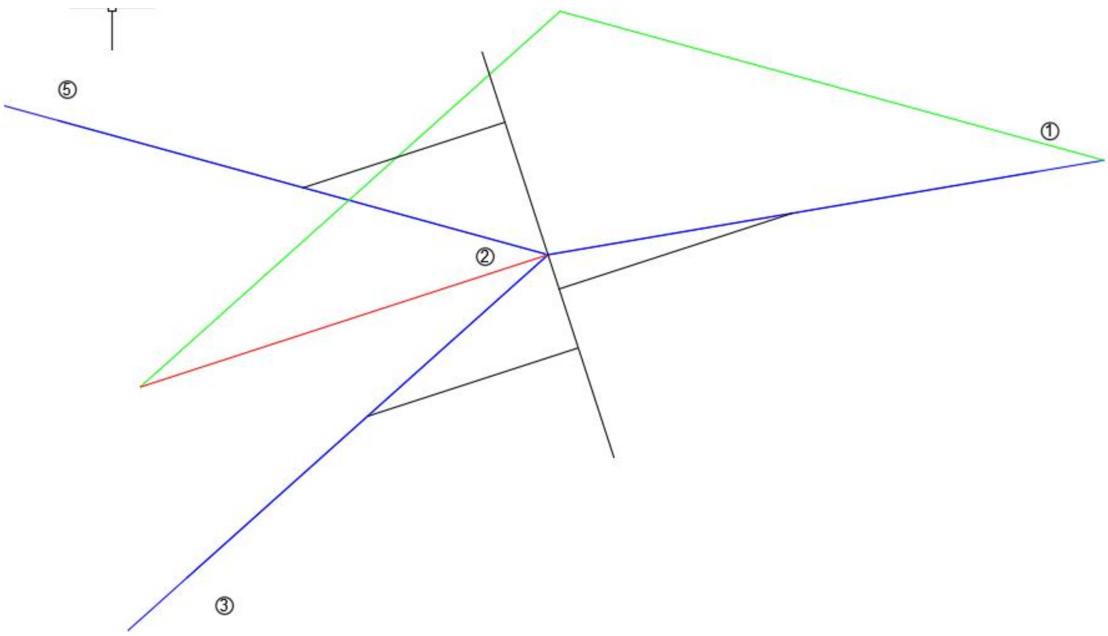
- DERIVATION 4

Derivation 4	Drawing (mm)	Real (m)	Cable
L 2-1	9,87	9,87	T-150
L 2-3	6,01	6,01	T-95
L 2-8	12,81	12,81	T-50
	Drawing (mm)	Real (daN)	
Fr	15,69	156,9	
Fv		55,91	
Ft		212,81	
Support		9/250	



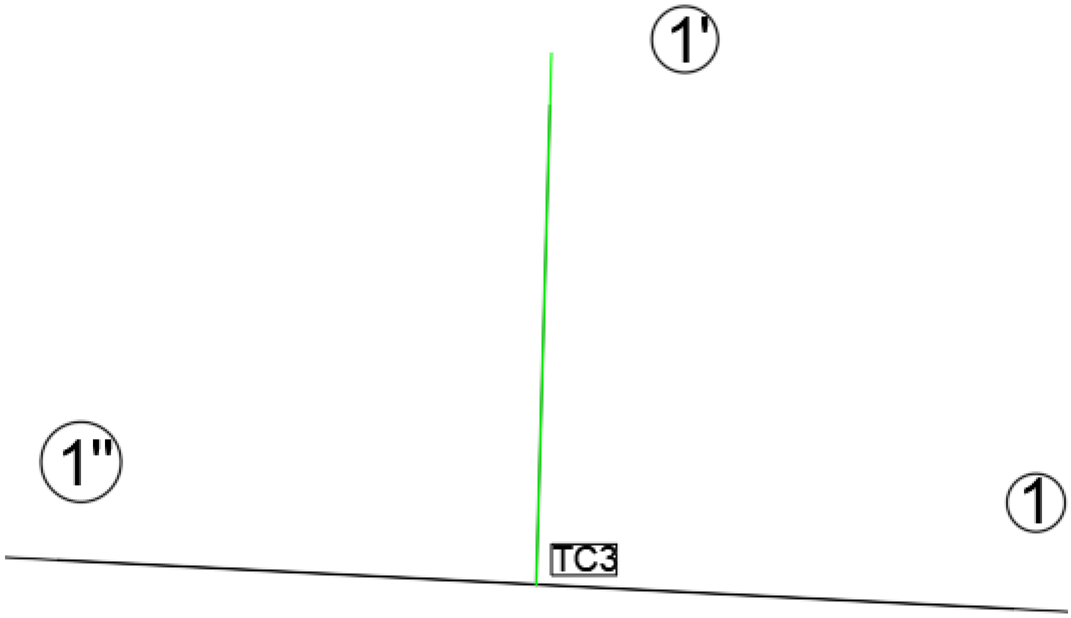
- DERIVATION 5

Derivation 5	Drawing (mm)	Real (m)	Cable
L 2-1	3,19	3,19	T-95
L 2-3	8,69	8,69	T-50
L 2-5	12,36	12,36	T-25
	Drawing (mm)	Real (daN)	
Fr	38,03	380,3	
Fv		33,848275	
Ft		414,148275	
Support		9/630	



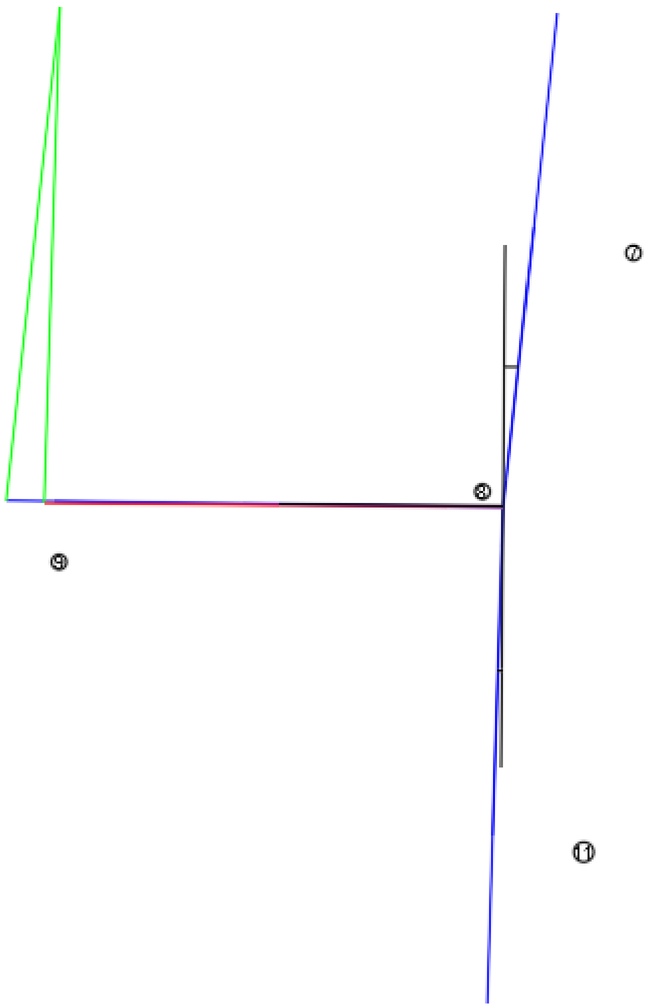
- DERIVATION 6

Derivation 6	Drawing (mm)	Real (m)	Cable
L TC3-1	25	25	T-95
L TC3-1’	0	0	T-95
L TC3-1’’	25	25	T-150
	Drawing (mm)	Real (daN)	
Fr	50	500	
Fv		112,3375	
Ft		612,3375	
Support		9/630	



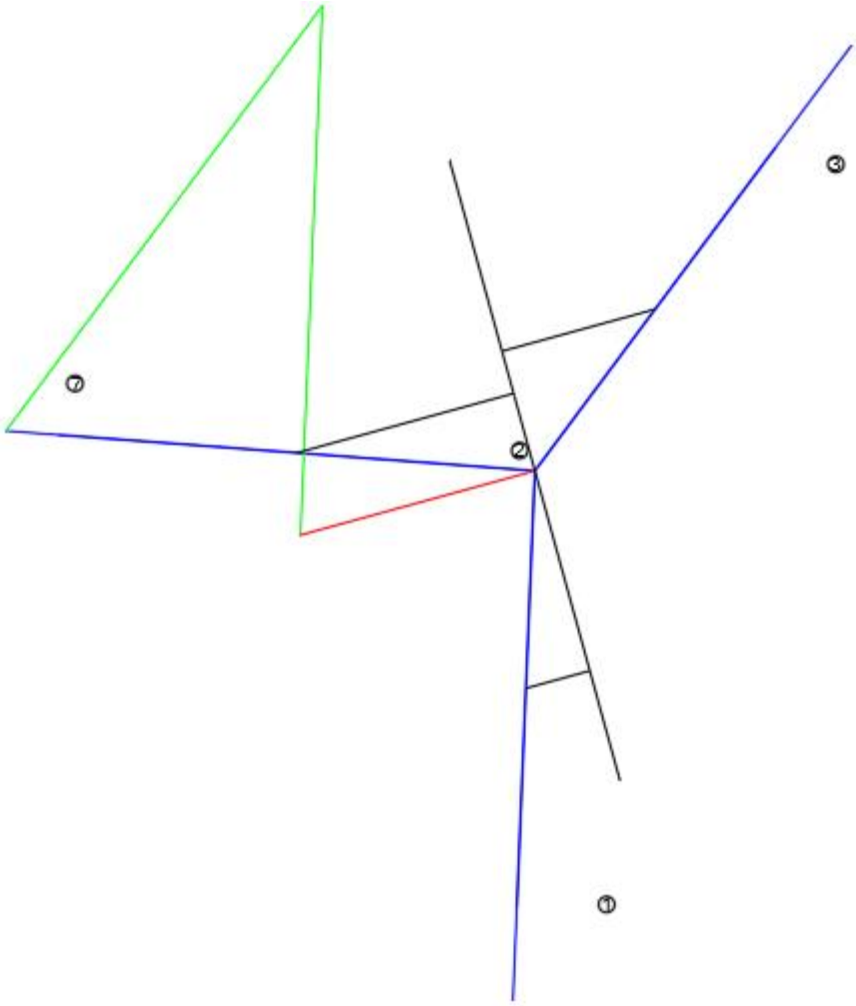
- DERIVATION 7

Derivation 7	Drawing (mm)	Real (m)	Cable
L 8-7	14,09	14,09	T-95
L 8-9	0,11	0,11	T-25
L 8-11	16,5	16,5	T-25
	Drawing (mm)	Real (daN)	
Fr	46,17	461,7	
Fv		47,675275	
Ft		509,375275	
Support		9/630	



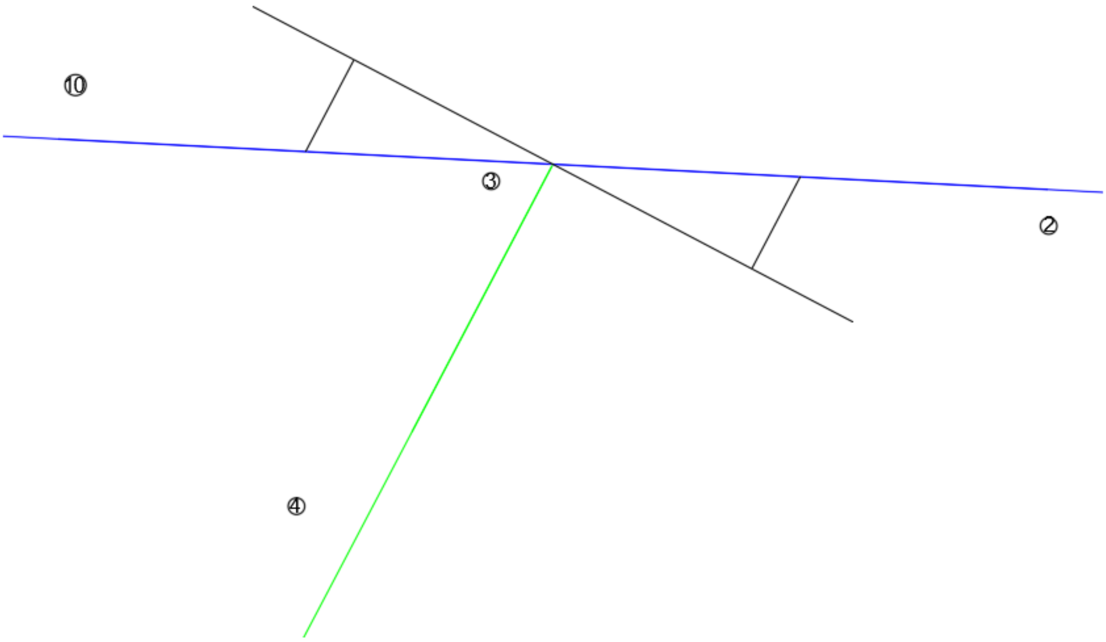
- DERIVATION 8

Derivation 8	Drawing (mm)	Real (m)	Cable
L 2-1	19,57	19,57	T-95
L 2-3	11,7	11,7	T-50
L 2-7	7,57	7,57	T-50
	Drawing (mm)	Real (daN)	
Fr	22,91	229,1	
Fv		68,775125	
Ft		297,875125	
Support		9/400	



- DERIVATION 9

Derivation 9	Drawing (mm)	Real (m)	Cable
L 3-2	20,42	20,42	T-150
L 3-4	0	0	T-150
L 3-10	20,42	20,42	T-95
	Drawing (mm)	Real (daN)	
Fr	50	500	
Fv		91,75727	
Ft		591,75727	
Support		9/630	



ANNEX 4

Tables of mechanical calculation middle voltage conductor. Zone A. [28]

LA-56

TABLA DE CALCULO MECANICO - ZONA A (Altitud de 0 a 500 m)
Conductor: LA 56 [47-AL1/8-ST1A]
Tracción Máxima: 543 daN

Secion, mm2 = 54,6
Diametro, mm = 9,45 mm
Coeficiente dilatación/°C = 0,0000191
Módulo de Elasticidad, daN/mm2 = 8100

Carga de Rotura, daN = 1629
Peso, kg/m = 0,189

Vano de Regulación m	Tensión máxima daN	Flecha m		-5 °C		-5 °C + 1/2V	-5 °C + V	15 °C		15 °C + V		50 °C		Parámetro Catenaria		CHS -5 °C	EDS 15 °C	85 °C		Vano de Regulación m
		Min.	Máx.	T daN	F m	T daN	T daN	T daN	F m	T daN	F m	T daN	F m	Min.	Máx.	%	%	T daN	F m	
20	422	0,02	0,36	409	0,02	412	422	245	0,04	276	0,11	50	0,18	2205	141	25,1	15,1	26	0,36	20
30	433	0,05	0,55	405	0,05	413	433	245	0,08	301	0,22	68	0,31	2188	206	24,9	15,1	38	0,55	30
40	447	0,09	0,74	401	0,09	415	447	246	0,15	327	0,37	83	0,45	2164	269	24,6	15,1	50	0,74	40
50	462	0,15	0,95	395	0,15	416	462	245	0,24	351	0,53	96	0,60	2134	328	24,3	15,1	61	0,95	50
60	477	0,21	1,17	389	0,21	418	477	245	0,34	375	0,72	109	0,77	2099	384	23,9	15,1	71	1,17	60
70	492	0,30	1,41	381	0,30	419	492	245	0,46	397	0,92	120	0,95	2060	436	23,4	15,1	80	1,41	70
80	507	0,40	1,65	374	0,40	421	507	245	0,60	418	1,15	128	1,15	2017	486	22,9	15,1	90	1,65	80
90	522	0,51	1,90	366	0,51	423	522	245	0,76	437	1,39	137	1,36	1973	532	22,5	15,1	99	1,90	90
100	535	0,65	2,17	357	0,65	425	535	245	0,94	455	1,64	145	1,59	1927	576	21,9	15,1	107	2,17	100
110	543	0,82	2,47	341	0,82	421	543	240	1,17	469	1,93	151	1,86	1836	612	20,9	14,7	114	2,47	110
120	543	1,06	2,82	316	1,06	408	543	229	1,46	475	2,27	153	2,18	1699	638	19,4	14,1	119	2,82	120
130	543	1,33	3,19	293	1,33	396	543	221	1,78	481	2,63	155	2,53	1577	661	18,0	13,5	123	3,19	130
140	543	1,66	3,59	275	1,66	386	543	213	2,13	485	3,02	156	2,91	1473	682	16,9	13,1	127	3,59	140
150	543	2,02	4,01	258	2,02	378	543	207	2,52	490	3,44	157	3,32	1387	700	15,8	12,7	130	4,01	150
160	543	2,42	4,46	245	2,42	371	543	202	2,94	494	3,88	159	3,75	1317	717	15,1	12,4	133	4,46	160
170	543	2,86	4,94	234	2,86	364	543	198	3,39	498	4,35	159	4,21	1260	731	14,4	12,2	135	4,94	170
180	543	3,33	5,44	226	3,33	358	543	194	3,86	501	4,84	160	4,69	1214	745	13,8	11,9	138	5,44	180
190	543	3,83	5,96	219	3,83	353	543	191	4,37	504	5,37	161	5,21	1176	757	13,4	11,7	140	5,96	190
200	543	4,36	6,52	213	4,36	349	543	189	4,91	507	5,91	162	5,75	1144	767	13,1	11,6	142	6,52	200
210	543	4,92	7,09	208	4,92	345	543	187	5,47	510	6,49	162	6,32	1118	777	12,8	11,5	144	7,09	210
220	543	5,51	7,70	204	5,51	342	543	185	6,06	512	7,09	163	6,91	1096	786	12,5	11,4	146	7,70	220
230	543	6,13	8,33	200	6,13	339	543	183	6,68	514	7,72	163	7,54	1077	794	12,3	11,3	147	8,33	230
240	543	6,78	8,99	197	6,78	336	543	182	7,33	516	8,38	163	8,19	1061	801	12,1	11,2	149	8,99	240
250	543	7,45	9,68	194	7,45	334	543	181	8,01	518	9,06	164	8,87	1047	808	11,9	11,1	150	9,68	250
260	543	8,16	10,39	192	8,16	332	543	180	8,71	519	9,77	164	9,57	1035	814	11,8	11,1	151	10,39	260
270	543	8,89	11,13	190	8,89	330	543	179	9,45	521	10,51	164	10,31	1024	819	11,7	11,0	152	11,13	270
280	543	9,65	11,90	188	9,65	330	543	178	10,21	522	11,28	165	11,07	1015	824	11,6	11,0	153	11,90	280
290	543	10,44	12,69	187	10,44	328	543	178	11,00	523	12,07	165	11,86	1007	829	11,5	10,9	154	12,69	290
300	543	11,25	13,52	185	11,25	327	543	177	11,81	525	12,89	165	12,68	999	833	11,4	10,8	155	13,52	300

ANNEX 5

Low voltage disconnectors catalogue [ABB manufacturer]

IEC	OTDC16F	OT16F	OT63F	OT100F	OT160EV		OT315E
	OTDC25F	OT25F	OT80F	OT125F	OT200E		OT400E
	OTDC32F	OT40F			OT250E		
UL		OT16F	OT63F	OT30F		OT200U	
		OT25F	OT80F	OT60F			
		OT40F		OT100F			

Tamaño del seccionador	16 25 32	16 25 40	63 80	30 60 100 125	160 200 250	200	315 400
IEC I_{th} [A]	25 32 45	25 32 40	63 80	115 125	160 200 250		315 400
I_e /AC22A, 415V [A]		16 25 40	63 80	100 125	160 200 250		315 400
I_e /AC23A, 415V [A]		16 20 23	45 75	80 90	160 200 250		315 400
I_e /DC21, 660V [A]	16 25 32	16 25 32			160 200 250		
I_e /DC21, 1000V [A]	16 25 32				160 200 250		315 400
I_e /DC21, 1000V, 2x660V [A]	16 25 32						
UL Corriente [A]		20 30 40	60 80	30 60 100		200	

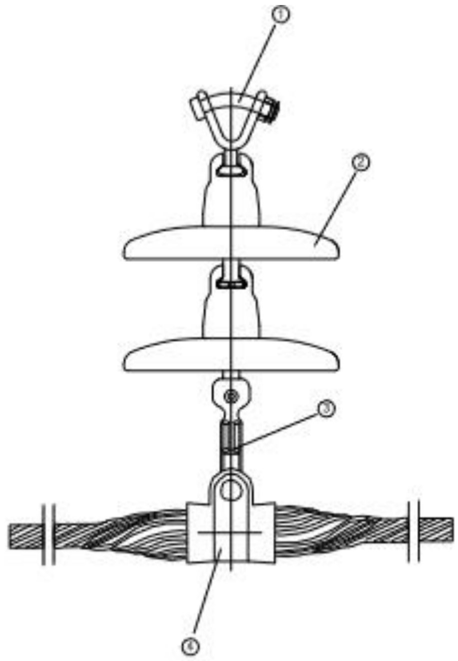
ANNEX 6

Middle/low voltage transformer catalogue [Legrand catalogue]

S_R [kVA]	Serie (Regl. 548)	N.º ref.	Uk [%]	Tensión del primario [kV]	Tensión del secundario [V]	Po [W]	Pk [W] a 120 °C	Io [%]	Potencia acústica LwA [dB (A)]	Longitud (A) [mm]	Anchura (B) [mm]	Altura (C) [mm]	Ic: línea central de las ruedas [mm]	R: diámetro de las ruedas (0) [mm]	Peso [kg]	Tipo de envolvente*
100	AoAk	FB4AAAGBA	6	20	400	280	1800	1,8	51	1300	660	1290	520	125	950	2
	AoBk	FB4ABAGBA	6	20	400	280	2050	1,8	51	1250	660	1250	520	125	900	2
160	AoAk	FC4AAAGBA	6	20	400	400	2600	1,6	54	1250	660	1370	520	125	1050	2
	AoBk	FC4ABAGBA	6	20	400	400	2900	1,6	54	1250	660	1300	520	125	1050	2
200	AoAk	FD4AAAGBA	6	20	400	450	2955	1,4	55	1350	660	1370	520	125	1200	3
	AoBk	FD4ABAGBA	6	20	400	450	3300	1,4	55	1350	660	1300	520	125	1200	3
250	AoAk	FE4AAAGBA	6	20	400	520	3400	1,2	57	1350	680	1420	520	125	1350	3
	AoBk	FE4ABAGBA	6	20	400	520	3800	1,2	57	1350	680	1420	520	125	1350	3
315	AoAk	FF4AAAGBA	6	20	400	615	3875	1,1	58	1350	750	1480	670	125	1450	3
	AoBk	FF4ABAGBA	6	20	400	615	4535	1,1	58	1350	750	1400	670	125	1450	3
400	AoAk	FG4AAAGBA	6	20	400	750	4500	1	60	1450	750	1570	670	125	1680	4
	AoBk	FG4ABAGBA	6	20	400	750	5500	1	60	1450	750	1570	670	125	1600	4
500	AoAk	FH4AAAGBA	6	20	400	900	5630	0,9	60	1450	750	1700	670	125	1800	4
	AoBk	FH4ABAGBA	6	20	400	900	6410	0,9	60	1450	750	1650	670	125	1800	4
630	AoAk	FI4AAAGBA	6	20	400	1100	7100	0,9	62	1550	850	1830	670	160	2150	5
	AoBk	FI4ABAGBA	6	20	400	1100	7600	0,9	62	1550	850	1830	670	160	2150	5
800	AoAk	FJ4AAAGBA	6	20	400	1300	8000	0,8	64	1550	850	1920	670	160	2550	5
1000	AoAk	FK4AAAGBA	6	20	400	1550	9000	0,7	65	1650	1000	2090	820	160	3150	6
1250	AoAk	FL4AAAGBA	6	20	400	1800	11000	0,7	67	1750	1000	2180	820	160	3650	6
1600	AoAk	FM4AAAGBA	6	20	400	2200	13000	0,5	68	1900	1000	2260	820	160	4600	7
2000	AoAk	FN4AAAGBA	6	20	400	2600	16000	0,5	70	2000	1310	2320	1070	200	5550	7
2500	AoAk	FO4AAAGBA	6	20	400	3100	19000	0,4	71	2150	1400	2450	1070	200	6300	8
3150	AoAk	FP4AAAGBA	6	20	400	3800	22000	0,4	74	2300	1400	2560	1070	200	8100	8

ANNEX 7

Middle voltage suspension set [28]



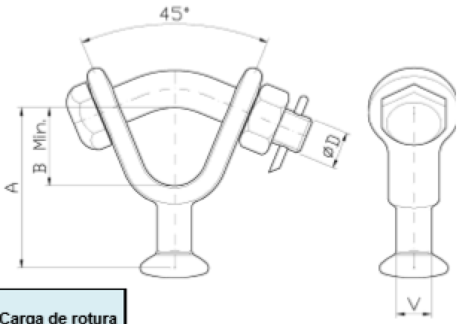
Number	ELEMENT	TYPE
1	Ball Y-Clevis	HB-16
2	Insulator	U 70 BS
3	Horn holder socket eye	R-16-P
4	Suspension clamp	GAS

Elements characteristics catalogue [MADE manufacturer]

"GAS" TYPE ARMOUR GRIP SUSPENSION CLAMP FOR ALUMINIUM CLAD STEEL CONDUCTOR.
PINCES DE SUSPENSION "GAS" PREFORME POUR CONDUCTEUR D'ACIER RECOUVERT D'ALUMINIUM

Referencia Code Référence	Ø Conductor Conductor Ø Ø Conducteur		Dimensiones en mm. Dimensions in mm. Dimensions en mm.								Nº varillas Nº of rods Nº de fils	Peso Weight Poids	Carga de rotura Ultimate strength Charge de ruptura
	Min.	Max.	A	B	C	ØD	Ød	E	F	P		Kg.	daN
S00210	8,71		1.270								8	1,365	
S00212	9,78		1.270	123	62	M-16	3,67	21	24	40	9	1,465	5.200
S00215	11,00		1.320								10	1,605	

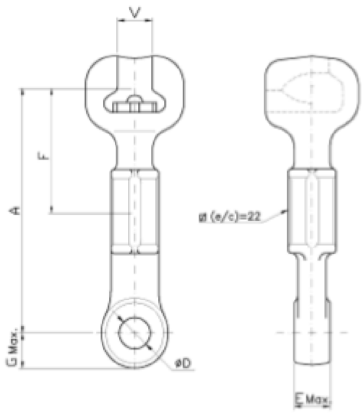
HORQUILLA BOLA EN "V"
BALL Y-CLEVIS
CHAPES EN V A ROTULE



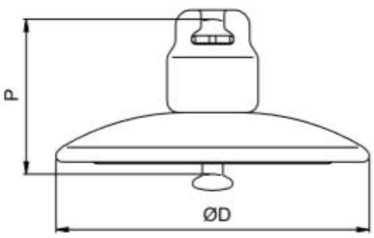
TIPO	Referencia Code Référence	Dimensiones en mm. Dimensions in mm. Dimensions en mm.			Norma C.E.I I.E.C Standard Norme C.E.I	Peso Weight Poids	Carga de rotura Ultimate strength Charge de ruptura
		A	B	ØD	V	Kg.	daN**
HB-16	N-247014/16	78	38	M-16	C.E.I. 16 mm	0,76	12.000
-	N-247014	78	38	M-18	C.E.I. 16 mm	0,83	13.500

ROTULA LARGA PARA PROTECCION
HORN HOLDER SOCKET EYE
BALL SOCKETS A TENON

TIPO	Referencia Code Référence	Dimensiones en mm. Dimensions in mm. Dimensions en mm.					Norma C.E.I I.E.C Standard Norme C.E.I	Peso Weight Poids	Carga de rotura Ultimate strength Charge de ruptura
		A	ØD	E	F	G	V	Kg.	daN
-	N-243180	140	17,5	16,5	71	-	C.E.I. 16 mm	0,640	9.000
-	N-243180/12	140	17,5	12,5	71	-		0,615	9.000
R-16-P	N-243181/16	140	17,5	16,5	71	22,5		0,860	13.500
-	N-243181/20	140	17,5	20,5	71	22,5		0,885	13.500
R-16-PA	N-243181/24	140	17,5	24,5	71	22,5		0,910	13.500
-	N-243181/32	140	17,5	32,5	71	23		0,955	13.500
-	N-243181/36	140	17,5	36,5	71	23		0,975	13.500
-	N-243181/44	140	17,5	44,5	71	23		1,015	13.500
-	N-243181/52	140	17,5	52,5	71	23		1,95	13.500
	R42631	139	17,5	18,5	71	25		1,41	21.500
	R42632	139	17,5	20,5	71	25		1,42	21.500
	R42633	139	17,5	24,5	71	25		1,43	21.500
	R42641	139	19,5	18,5	71	25		1,40	21.500
	R42642	139	19,5	20,5	71	25		1,41	21.500
	R42643	139	19,5	24,5	71	25		1,42	21.500
	R42661	139	21,5	18,5	71	25		1,40	21.500
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]



Insulator characteristics catalogue [INAEL manufacturer]

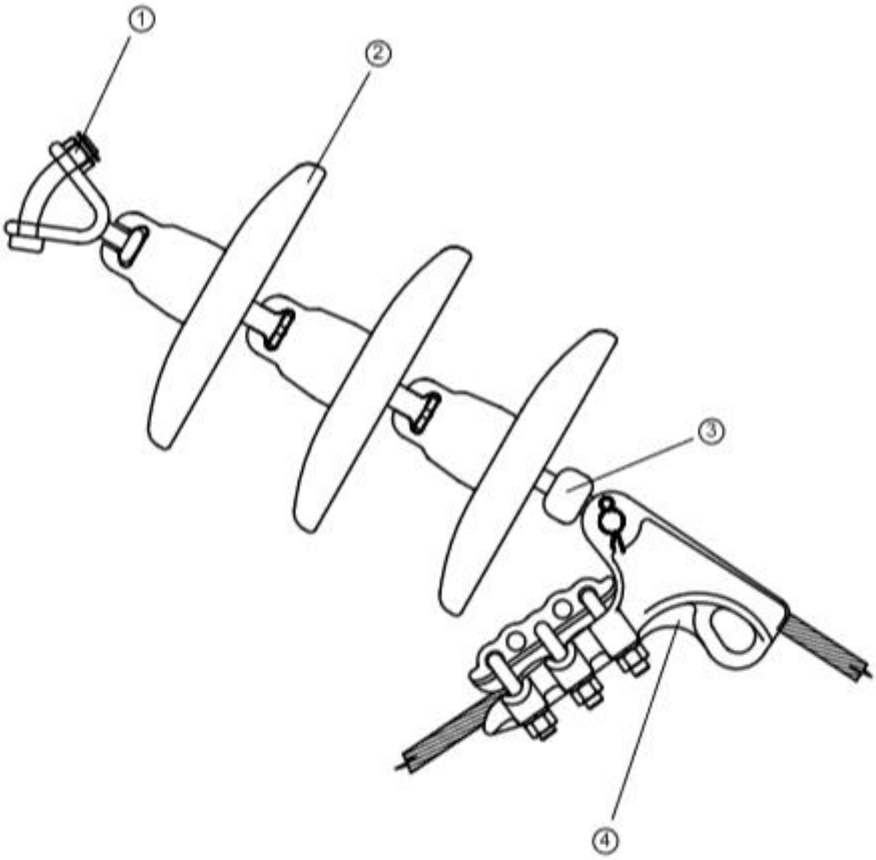


Características
Characteristics
Caractéristiques

Tipo Type	Dimensiones Dimensions Dimensions mm		Línea de fuga Creepage distance Ligne de fuite	Norma de acoplamiento Standard coupling Norme d' assemblage CEI 60 120	Carga rotura U.T.S. Charge de rupture	Peso Weight Poids	Uds/Caja Units/Box Unités/Carton
	P	D	mm		kN	Kg.	
U 40 B	110	175	190	11	40	1,7	9
U 70 BS	127	255	295	16	70	3,5	7
U 70 BL	146	255	295	16	70	3,5	7
U 100 BS	127	255	295	16	100	3,7	7
U 120 B	146	255	295	16	120	3,8	7

ANNEX 8

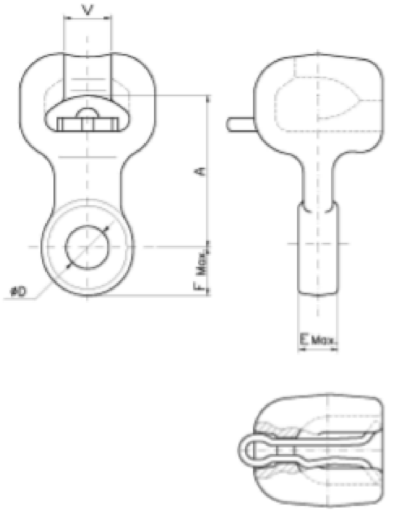
Middle voltage tension set [28]



Number	ELEMENT	TYPE
1	Ball Y-Clevis	HB-16
2	Insulator	U 70 BS
3	Socket eye	R-16
4	Strain clamp	GA-1/1

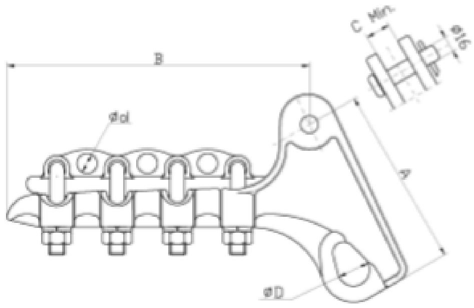
Elements characteristics catalogue [MADE manufacturer]

ROTULA CORTA
SOCKET EYE
BALL SOCKETS



TIPO	Referencia Code Référence	Dimensiones en mm. Dimensions in mm. Dimensions en mm.				Norma C.E.I I.E.C Standard Norme C.E.I	Peso Weight Poids	Carga de rotura Ultimate strength Charge de ruptura
		A	ØD	E	F	V	Kg.	daN
R-16	N-243062/16	64	17,5	16,5	22,5	C.E.I. 16 mm.	0,58	13.500
-	N-243062/20	64	17,5	190,5	22,5		0,62	13.500
R-16A	N-243062/24	64	17,5	24,5	22,5		0,65	13.500
-	N-243062/32	64	17,5	32,5	23		0,74	13.500
-	N-243062/36	64	17,5	36,5	23		0,76	13.500
-	N-243062/44	64	17,5	44,5	23		0,80	13.500
-	N-243062/52	64	17,5	52,5	23		0,85	13.500

GRAPAS DE AMARRE TIPO "GA"
"GA" TYPE STRAIN CLAMP
PINCES D'ANCRAGE TYPE "GA"



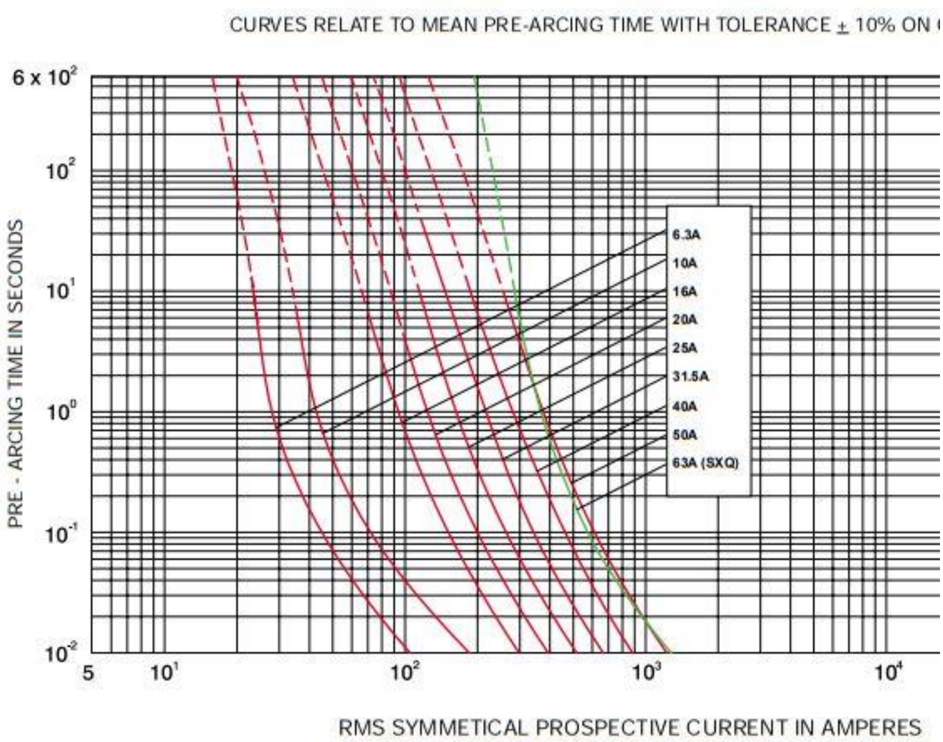
Tipo de grapa Clamp type Pince type	Referencia Code Référence	Ø Conductor Conductor Ø Ø Conducteur		Dimensiones en mm. Dimensions in mm. Dimensions en mm.					Par de apriete Tightening torque Couple de serrage	Estribos U-bolts etriers		Nº agujeros zapata Nº Hole brake shoe	Peso Weight Poids	Carga de rotura Ultimate strength Charge de ruptura
		Mín	Máx	A	B	C	ØD	Ød	N.m.	Rosca	Nº	Nº trou mâchoire	Kg.	daN
GA-1	244205	4	10	80	98	18	16	13	25	M-10	2	1	0,43	2.500
GA-1/1	244206	5	11,5	125	118	18	16	13	35	M-12	2	1	0,65	3.500
GA-2	244207	9,4	16	135	181	18	22	15	50	M-12	3	2	1,12	5.500
GA-3	244208	14	20	165	252	21	22	15	50	M-12	4	2	1,82	8.000
GA-4	G11126	18	25,5	210	309	27	30	-	90	M-16	4	-	3,50	10.500

ANNEX 9

Middle voltage fuses characteristics [Bussman manufacturer]

Part Number	Voltage Rating	Current Rating	Breaking Capacity	Minimum Breaking Current	Cold resistance and watts loss in free air at rated current		Joule Intergral (I^2t)		Length	Diameter ø	Weight
	U_n	I_n	I_1	I_3			A^2s				
	kV	A	kA	A	m Ω	W	Minimum Pre-Arcing	Maximum Total Clearing	mm	mm	kg
12FDLSJ6.3	12	6.3	50	6.3	208	10	$6.9X10^1$	$6.3X10^2$	292	50.8	1.63
12FDLSJ10	12	10	50	10	116	15	$2.2X10^2$	$2.1X10^3$	292	50.8	1.63
12FDLSJ16	12	16	50	16	55.4	17	$8.8X10^2$	$3.9X10^3$	292	50.8	1.63
12FDLSJ20	12	20	50	20	39.6	20	$1.7X10^3$	$7.6X10^3$	292	50.8	1.63
12FDLSJ25	12	25	50	25	31.2	26	$2.8X10^3$	$1.3X10^4$	292	25.8	1.63
12FDLSJ31.5	12	31.5	50	31.5	26.4	36	$2.6X10^3$	$1.3X10^4$	292	50.8	1.63
12FFLSJ40	12	40	50	40	19.7	42	$3.8X10^3$	$3.8X10^4$	292	76.2	3.16
12FFLSJ50	12	50	50	50	14.8	51	$6.8X10^3$	$5.6X10^4$	292	76.2	3.16
12FFLSJ63	12	63	50	63	12.4	72	$5.1X10^3$	$5.4X10^4$	292	76.2	3.16
12FXLSJ80	12	80	50	80	7.94	72	$2.2X10^4$	$1.1X10^5$	292	88	4
12FXLSJ100	12	100	50	100	5.64	82	$4.2X10^4$	$2.0X10^5$	292	88	4
24FDMSJ6.3	24	6.3	35.5	6.3	437	21	$6.8X10^1$	$5.4X10^2$	442	50.8	2.2
24FDMSJ10	24	10	35.5	10	218	29	$2.7X10^2$	$2.1X10^3$	442	50.8	2.2
24FDMSJ16	24	16	35.5	16	118	39	$8.2X10^2$	$2.7X10^3$	442	50.8	2.2
24FDMSJ20	24	20	35.5	20	82.2	43	$1.6X10^3$	$5.1X10^3$	442	50.8	2.2
24FDMSJ25	24	25	35.5	25	54.7	48	$3.4X10^3$	$1.2X10^4$	442	50.8	2.2
24FDMSJ31.5	24	31.5	35.5	31.5	48.6	71	$3.2X10^3$	$1.2X10^4$	442	50.8	2.2
24FFMSJ25	24	25	35.5	25	58.6	47	$3.4X10^3$	$1.1X10^4$	442	76.2	4.5
24FFMSJ31.5	24	31.5	35.5	31.5	48.8	70	$4.7X10^3$	$1.5X10^4$	442	76.2	4.5
24FFMSJ40	24	40	35.5	40	38.4	85	$7.6X10^3$	$2.5X10^4$	442	76.2	4.5
24FFMSJ45	24	45	35.5	45	31.4	92	$7.2X10^3$	$3.0X10^4$	442	76.2	4.5

i-t characteristics



ANNEX 10

Middle voltage disconnector catalogue [Inael manufacturer]

Características

Characteristics

Caracteristiques

Tipo Type Type	U_r kV *	Ith kA	I_r A	Dimensiones Dimensions Dimensions mm					Línea de fuga Creepage distance Ligne de fuite	Carga rotura Failing load Charge rupture	Peso Weight Poids
				A	B	C	D	E	mm	N	kg
SU 1.110	17.5	16	400 ó 630	332	200	522	464	356	625	3.000	16
	24			382	200	572	464	356	625		18
	28			410	270	600	569	456	925	2.500	24
	36			480	270	670	569	456	925		26

ANNEX 11

Middle voltage lighting arrester characteristics catalogue [Siemens manufacturer]

Tensión asignada U_r [kV]	Tensión de operación permanente U_c [kV]	Referencia del pararrayos
3	2,4	3EK7 030 -4CB4
5	4	3EK7 050 -4CB4
6	4,8	3EK7 060 -4CB4
9*	7,2	3EK7 090 -4CB4
10,5*	8,4	3EK7 105 -4CB4
12*	9,6	3EK7 120 -4CC4
15*	12	3EK7 150 -4CC4
18*	14,4	3EK7 180 -4CD4
21*	16,8	3EK7 210 -4CD4
22*	17,6	3EK7 220 -4CE4
24*	19,2	3EK7 240 -4CE4
25	20	3EK7 250 -4CE4
27	21,6	3EK7 270 -4CF4
30*	24	3EK7 300 -4CF4
31,5	25,2	3EK7 315 -4CH4
33	26,4	3EK7 330 -4CH4
36*	28,8	3EK7 360 -4CH4
39	31,2	3EK7 390 -4CH4
42	33,6	3EK7 420 -4CH4
45	36	3EK7 450 -4CH4
48	38,5	3EK7 480 -4CK4
50,5*	40,5	3EK7 505 -4CK4
51	41	3EK7 510 -4CK4
54	43,2	3EK7 540 -4CK4
57	45,6	3EK7 570 -4CK4
60	48	3EK7 600 -4CK4

Tensión máxima del equipamiento U_m [kV]	Tensión de impulso atmosférico normalizado [kV]
2,75	30; 45; 60
3,6	20; 40
5,5	45; 60; 75
7,2	40; 60
8,25	60; 75; 95
12	60; 75; 95
15,5	75
15,5	85; 110
17,5	75
17,5	95
24	95
24	125; 145
25	125; 145
27	95
27	125
27	150
30	160
36	145
36	170
38	125
38	150
38	200
40,5	190
48,3	150
48,3	200
48,3	250
52	250
72,5	325

ANNEX 12

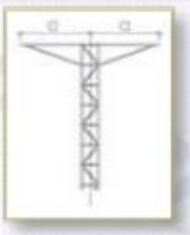
Middle voltage support and crossarms catalogue [IMEDEXSA manufacturer]

Supports type "C"

ALTURA NOMINAL		ESFUERZOS						
		500	1.000	2.000	3.000	4.500	7.000	9.000
10	HPC	8,8	8,37	8,29	8,1	7,7	...	...
	Peso	242	263	397	486	623	...	...
12	HPC	10,75	10,31	10,04	10,04	9,63	9,77	9,61
	Peso	301	325	479	592	764	1147	1295
14	HPC	12,71	12,28	12,14	11,8	11,59	11,75	11,59
	Peso	356	400	582	719	946	1352	1533
16	HPC	14,67	14,24	14,09	13,86	13,53	13,75	13,59
	Peso	413	461	682	866	1097	1593	1805
18	HPC	16,65	16,21	16,12	15,73	15,52	15,75	15,58
	Peso	472	544	804	991	1304	1795	2090
20	HPC	18,44	18,2	18,1	17,71	17,5	17,75	17,58
	Peso	541	624	921	1149	1513	2053	2413
22	HPC	20,6	20,16	20,07	19,68	19,47	19,75	19,58
	Peso	630	722	1040	1304	1717	2321	2691
24	HPC	22,58	22,14	22,05	21,65	21,44	21,75	21,58
	Peso	715	815	1169	1472	1904	2598	3023
26	HPC	24,35	24,32	24,04	23,72	23,44	23,75	23,58
	Peso	780	916	1296	1639	2149	2936	3322
28	HPC	26,53	26,11	26,01	25,62	25,41	25,75	25,58
	Peso	872	1008	1440	1804	2384	3279	3723
30	HPC	28,32	28,29	27,83	27,61	27,41	27,59	27,58
	Peso	940	1116	1570	1956	2593	3575	4062

Crossarms type "L"

Tipo	Peso (Kg)		
	a (m)	500/4.500	7.000/9.000
L0	1,00	30	56
L1	1,25	36	74
L2	1,50	42	104
L3	1,75	46	114
L4	2,00	66	128



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