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Assessment of connecting electric vehicles charging points at B:SM facilities to railway infrastructure

per a

B:SM

B:SM Barcelona de Serveis Municipals

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Terminology

AC	Alternating Current
DC	Direct Current
LV	Low Voltage
HV	High Voltage
ITC	Instrucción Técnica Complementaria (belongs to REBT)
REBT	Electric rules for Low Voltage installations
RAT	Electric rules for High Voltage installations
EV	Electric Vehicle
FGC	Ferrocarrils de la Generalitat de Catalunya
OCCP	Open Charge Point Protocol

1. Introduction

The objective of this study is the assessment of connecting electric vehicles charging points at B:SM facilities to the railway infrastructure existing in the undergroundpolitan area of Barcelona. B:SM facilities includes off-street (underground) and on-street parking lots. The railway infrastructure comprises the installations of Underground, TRAM, FGC (Ferrocarrils de la Generalitat de Catalunya) and ADIF.

As both railway facilities and B:SM parking lots are spread over the city, and sometimes they are very close, there is the opportunity for charging electric vehicles parked at B:SM facilities with energy coming from electric network of the railway installations, according to the disposal of power and energy at each moment in the different places.

The present study proposes the electrical infrastructures that would enable to profit of this available electrical energy. Their techno-economic feasibility is analysed, taking into consideration the existing regulatory frame.

1.1. Objective and tasks

In order to achieve the objective of this study, proposal of the electrical infrastructure for charging electric vehicles at B:SM from railway infrastructure, the following tasks have been developed:

- Identification of technical requirements for the new infrastructure
- Technical and economical assessment of the proposals for such new infrastructure
- Operation and maintenance needs of the new infrastructure
- Cost estimation of the new infrastructure
- Legacy assessment

1.2. Methodology

This study has been developed according to the description of electrical and operational characteristics of current electric vehicle charging points and existing railway infrastructure that B:SM facilitated. The information regarding B:SM charging points is depicted in the Annex.

Then, based on extending the existing railway infrastructure (Underground, TRAM, FGC and ADIF), a new electrical infrastructure has been proposed taking into account the general characteristics of each railway installation and also considering the existing Electric Codes. The installation and maintenance costs of the elements composing such new electrical infrastructure have been estimated, too. Finally, legal issues affecting the new infrastructures have been indicated.

2. Definition of the existing Public Transport network

With more than one hundred stations, present on all of Barcelona’s districts, Barcelona’s Underground Network supplies public transport for nearly 500.000 users per year. The electric network of the underground system has a positive scalability that could not only work in favour of the rail system but transcend to supply energy to the electric powered surface vehicles.

The typical electrical network layout for railway transportation is shown in Figure 1. The power supply network is a high voltage (HV), alternating current (AC) and three-phase system that feeds the traction system and the auxiliary systems, such as lighting, elevators and the rest of equipment placed at railway stations.

All the railway transports analysed in the present study (underground, tram, ADIF-RENFE trains and FGC) have their catenary fed in DC. So, as represented in Figure 1, the catenary is connected to the power supply bus through a power electronic converter.

The auxiliary services are connected to a low voltage (LV) AC bus. Therefore, a step- down transformation is needed from the power supply bus. In fact, this step-down transformation is usually done in 2 steps. A transformer adapts the voltage of the power supply network to the own distribution network, which is HV, AC and three-phase, and this provides electricity to the transformation centres (TCs) at each station. The TCs are in charge of transforming the voltage from the distribution network to the required LV network for the auxiliary services.

Another possible layout consists of feeding the auxiliary services directly from an electric distribution company. This configuration is shown in Figure 2 .

Table 1 summarizes the electrical characteristics of the railways analysed in this study.

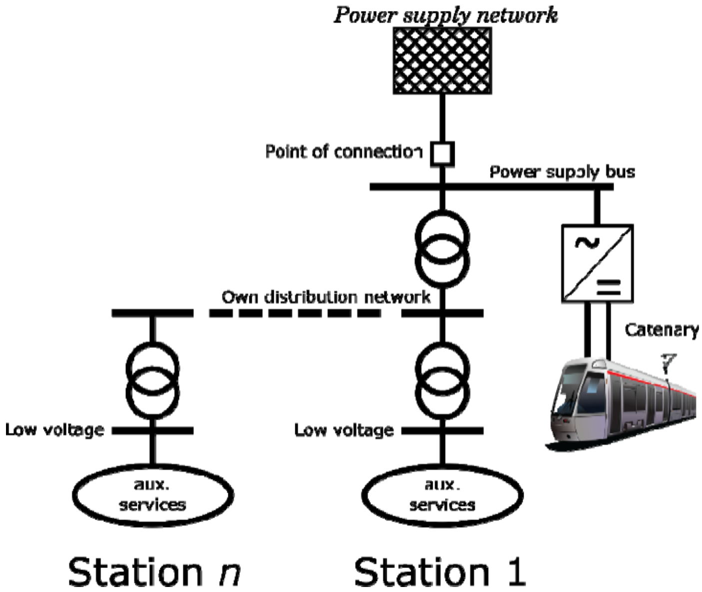


Figure 1. Typical railway electrical layout. Source: Own elaboration

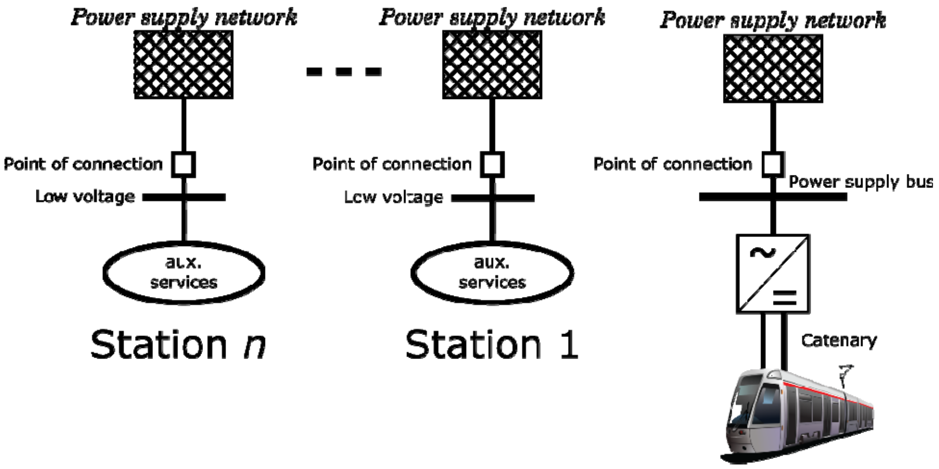


Figure 2. Railway electrical layout with external feeders for auxiliary services. Source: Own elaboration

Electric network part	Underground	Tram	ADIF-RENFE	FGC
Power supply bus	3-phase 25 kV$_{AC}$ 3-phase 11 kV$_{AC}$	3-phase 25 kV$_{AC}$ (2)	3-phase 25 kV$_{AC}$ (2)	3-phase 25 kV$_{AC}$ 3-phase 11 kV$_{AC}$
Catenary	1.2 kV$_{DC}$ 1.5 kV$_{DC}$	750 V$_{DC}$	1.5 kV$_{DC}$ 3 kV$_{DC}$ 25 kV$_{AC}$ 3-phase (1)	1.5 kV$_{DC}$
Own distribution network	3-phase - 6 kV$_{AC}$	3-phase - 3-11 kV$_{AC}$	3 kV$_{AC}$ 1-phase 3 kV$_{AC}$ 3-phase	3-phase - 6 kV$_{AC}$ 3-phase - 11 kV$_{AC}$
Low voltage supply	3-phase 400 V$_{AC}$ 3-phase 230 V$_{AC}$	1-phase 230 VAC (2)	3-phase 400 V$_{AC}$ 3-phase 230 V$_{DC}$ (2)	3-phase 400 V$_{AC}$ 3-phase 230 V$_{DC}$ (2)

Sources: [1], [2], [3], [4], [5], [6] and [7].

(1) The 25 kV$_{AC}$ 3-phase catenary is only used in high speed trains of ADIF-RENFE (AVE). These railways are out of the scope of the present study.

(2) No documentation found. Moss probable values.

Table 1. Electrical characteristics of the different railway electrical infrastructure in Barcelona

2.1. Underground

The electrical characteristics of the Barcelona’s underground network are shown in Figure 3. At the underground substation, the external power supply is a 3-phase 25 kV$_{AC}$ network [2]. This voltage is transformed to 1.2 or 1.5 kV$_{DC}$ network (depending on the underground line) which feeds the underground catenary. In addition, a 6 Kv$_{AC}$ 3-phase sub-transmission network is generated. This later network feeds each underground station. For this purpose, the energy is transmitted to the transformation centres (TCs) at each underground station. These TCs transform the 3-phase 6 Kv$_{Ac}$ sub-transmission network to 400 V$_{AC}$ 3-phase network for the ventilation or vertical transport (for instance stairs and lifts) and to 230 V$_{ACc}$ 3-phase network to feed other single-phase equipment such as lighting. These single-phase equipment is connected between the active phases (r, s, t). So, neutral wire is not required [1], [2].

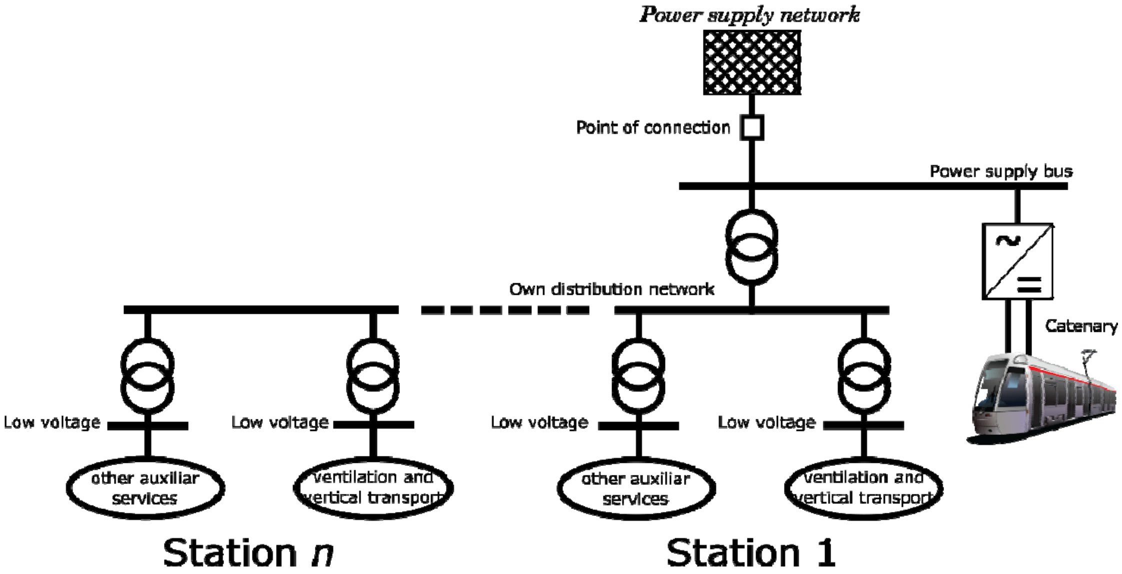


Figure 3. Layout of the underground electrical network. Source: Own elaboration

2.2. Tram

The Barcelona’s tram is fed from 6 substations that convert external HV three-phase network to 750 V_{dc} lines (used for traction purposes) [6]. On the other hand, there is no public information about the auxiliary power supply. As there is no necessity of ventilation at the stations, and they are small compared to the underground stations, it is likely that the auxiliary power supply comes from a low voltage network of a distribution company (Fig. 2).

2.3. Railway ADIF-RENFE

ADIF-RENFE railway is fed using 1.5 kV_{DC}, 3 kV_{DC} or 25 kV_{AC} catenary depending on the line [3], [5]. Regarding the auxiliary services, the command and signalling systems are fed from 1-phase 3 kV_{AC} and 3-phase 3 kV_{AC} networks [4]. There is no public information about how the rest of auxiliary services are fed.

2.4. Railway FGC

Similar to the underground, the railway operated by FGC has an external power supply of 25 kV_{AC} 3-phase system [2]. Then, this voltage is transformed to 1500 V_{DC} feeding the catenary for traction purposes. In addition, the external power supply is transformed to an internal 3-phase 6 and 11 kV_{AC} system for the auxiliary power supply at stations [7]. There is no public information about how the auxiliary supply is performed, but due to the characteristics of the common devices, it should be done through 3-phase 400 V_{AC} or 1-phase 230 V_{AC} (which corresponds to the phase-neutral voltage in a 3-phase 400 V_{AC} system). According to this description, the FCG and underground electrical infrastructure are closely similar.

3. Use of the actual Railway Public Transport network to power Electric Vehicle recharging points

The present chapter has the goal to describe how the railway energy network will be used in order to feed electric vehicles. The main points of the chapter are:

- Potential use of the actual network: Overlapping both, railway network and electric vehicles recharging points networks, this point will help understand the actual potential of the railway grids to feed the recharging points used nowadays.
- Scalability and main growth constraints: This point will help understand how the railway network could feed an expanding network of recharging points and the main constraints for its growth.

3.1. Potential use of the actual network

On the one hand, railway infrastructures are spread across the city of Barcelona. As it has been depicted in Section 2, such railway infrastructures usually include a catenary for traction proposes and an own distribution network which is used for feeding the auxiliary systems at the stations. This could be seen as a means for distributing energy to external consumptions apart from railway itself due to that, at some periods, it power capability is unused. During the railway service hours, usually from 6:00 to 24:00 h, such electric infrastructures are plenty used although the consumption is not constant and varies during this period according to the mobility requirements. However, at off-service period, own consumption is highly reduced, and then, more power is available and more constant.

On the other hand, charging points for electric vehicles at parking lots from B:SM are also distributed over the city, as it has been exposed in the Annex. Rental parking lots with an electric vehicle usually will usually charge the vehicle at night because is when the vehicle is parked and the price of the energy is cheaper, too. Furthermore, the more time a vehicle is parked, the lower is the power required at the charging point to charge its battery. This exactly matched with off-service period of railway, representing the most convenient situation. Nevertheless, temporary users of parking lots with an electric vehicle could ask for a charging at any time. Depending on the time the EV will be parked, the power requested will be different. For example, if the user will go shopping or to the cinema/theatre, that expected time might vary between 1 to 3 hours. So, during this time, the user takes the opportunity to charge its vehicle. But if the user need to charge for an emergency because it does not have enough energy to get its destination, it likely aims to charge on-street installation in up to 15 minutes. Therefore, for temporary users, an active management with a monitoring system will be required for permitting charging.

In this situation, as some B:SM facilities are reasonably closed to some railway station, the opportunity for linking the charging of electric vehicles from railway infrastructure appears as an alternative to usual power supply from distribution company. Such opportunity is high at off-service period at railway services with typical charging period of rental parking lots. In the other periods, there is still a chance, but with some constraints that can be solved if the proper means are available.

3.2. Scalability and main growth constraints

Scalability of the new infrastructure is understood as the capacity of such system to supply energy to new charging points in the area of study, that is, Barcelona.

On one hand, such new infrastructure can be built on places where there is power unused from railway services. However, when there no power unused, in order to make it available, an upwards upgrade of existing railway installation is required, that represents a higher complexity and cost to deploy it.

On the other hand, new charging installations can be installed in existing EV parkings or in new parkings. The first, will affect both, the railway electric infrastructure and the existing distribution line from railway electric network to the EV facilities. The last, new EV parkings will affect the metro infrastructure and will require new electrical infrastructure (power supply line).

It exists the opportunity of using railway infrastructure for feeding charging points for electric vehicles at parking lots from B:SM. However, there are different constraints that have to be taken into account:

- Railway infrastructures have been designed considering only own consumption and their usual growth.
- Power unused from railway varies during service hours. Moreover, it is likely it varies from station to station.
- It is required a coordination between charging points operation and railway requirements at any moment.
- Regulatory issues have to be solved to take advantage of this opportunity.

4. Description of the solution

Once the opportunity of feeding electric vehicles from railway infrastructure has been exposed in previous chapters, in this section the proposed new infrastructure is explained. It starts with the state of the art and legal framework, followed by the technical requirements. At this point, the different infrastructure design options are introduced and discussed, depicting later their technical and use parameters. Afterwards, its operation, maintenance and performance necessities are noted. Finally, the main cost drivers are identified in order to later define the cost of the installation of the infrastructure defined in the future scenarios.

4.1. State of the art

Next table summaries recent projects involving EV charging and railway infrastructure.

Name	Country	Year	Description
Electric Vehicle Charging Infrastructure at Maryland Rail Stations Study	Maryland, USA	2013	http://www.mdot.maryland.gov/Office_of_Planning_and_Capital_Programming/Electric_Vehicle/Documents/EVSE_AT_MD_Transit_Stations_111313.pdf 1000000 $ funds to install EV Charging units at rail stations. The project concludes where must be the charging points installed, how, which types and when.
Electric Vehicle Charging Stations fed by Renewable: PV and Train Regenerative Braking	Jaen, Spain	2016	http://www.merlin-rail.eu/ MERLIN’s main aim and purpose is to investigate and demonstrate the viability of an integrated management system to achieve a more sustainable and optimised energy usage in European electric mainline railway systems. http://ieeexplore.ieee.org/document/7587629/ DC Microgrid architecture with renewable energy sources
Train2car	Madrid, Spain	2016	Train2Car project – How to charge electric vehicles with green energy through regenerative braking of metro trains http://frevue.eu/wp-content/uploads/2016/05/Technical-1-Multimodality-Sharing-and-Optimising-Charging-Infrastructure.pdf
TransEnergy project	Britain	2016	The aim of the project investigate how battery storage solutions could be used to help power Britain’s railways. The project is supported by National Rail and funded by the Engineering and Physical Sciences Research Council (EPSRC) and will investigate two types of energy storage - batteries and supercapacitors - as a hybrid solution for the high levels of electricity needed to power trains accelerating and charge from trains braking. Budget for 3 years: £1.5 million http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/N022289/1

4.2. Legal framework

The proposal of the new infrastructure that is detailed in this section has two main legal concerns:

- Safety in the installation
  Safety is achieved by considering Electrical Codes where technical issues for assuring safety are specified. There are three items:
  - High voltage facilites [9]
  - High voltage power lines 0
  - Low voltage [10]
    It should be mentioned that a specific instruction for electric vehicle installation has been added, ITC-BT-52 [11]
- Participants
  - Power System Law [12]
    It defines the different activities included in energy supply: generation, transmission, distribution, charging manager, retailing, international exchanges, system operator, market operator.
    According to the aim of the new infrastructure, and the role of the different participants described in the Law, this new infrastructures might belong to a distributor or a charging manager. Nevertheless, as charging manager is a consumer able to resell its energy to third-ones for charging proposes, the more suitable owner of such new infrastructure seems to be a distributor.

4.3. Technical requirements analysis

In order to define the new infrastructure to be built, it is necessary to characterize the technical requirements of its origin and end. The *origin* corresponds to the point of the railway where the new infrastructure begins. The *end* corresponds to the point of the electrical charging station where the General Protection Box is located.

Origin: Railway substation
The railway substation layouts are showed in Section 2, where the electrical infrastructure of the underground, Tram, FGC and ADIF is characterized. Their infrastructures are already built, so the requirements for their extension will be restricted to the specifications of the EV charging point at the B:SM facilities they need to feed.

End: LV board at B:SM facilities
The EV charging points characteristics influence the electrical infrastructure to be developed starting from the railway feeding point and ending at the supply point of the EV charging station. In this sense, the REBT ("*Reglamento Electrotécnico de Baja tensión"*) and namely ITC-BT-52 ("*Instal·lacions amb fins especials. Infraestructura per a la recàrrega de vehicles elèctrics*") must be taken into account.

EV charging points installed can be classified in:

a) AC single-phase (230 V) with usual power rating between 3.6 and 7.2 kW
b) AC three-phase (400 V) with usual power rating between 11 and 22 kW
c) Direct current (DC) with usual power rating between 20 and 50 kW

The choice of a), b) or c) depends on the location of the EV charging point and on the charging mode offered. EV charging points located in internal installations can be type a) or type b), while EV charging points located in outdoor installations can be type a), b) or c). The possible **charging modes and connectors** are defined by the IEC 61851 and IEC 62196 respectively, as they are referenced in ITC-BT-52:

- Mode 1: charging from a regular electrical socket (single or three-phase AC). The EV is connected to the AC supply network through normalized power outlets.
- Mode 2: charging from a regular socket but with a protection arrangement in the cable (single or three-phase AC).
- Mode 3: charging using a specific EV socket with control and protection functions (single or three-phase AC).
- Mode 4: DC charging. It needs an external charger.

According to ITC-BT-52, the normalized powers for collective EV charging circuits dedicated to feed charging stations are shown in Table 2. The number of charging stations is restricted depending on the power installed. However, as stated in the ITC, the person developing the installation can increase or decrease the number of charging stations, justifying an installed power per station lower or larger, respectively.

U_{rated}	Overcurrent protection at the beginning of the charging circuit	Installed power	Maximum number of charging stations per circuit
230/400 V	16 A	11085 W	3
230/400 V	32 A	22170 W	6
230/400 V	50 A	34641 W	9
230/400 V	63 A	43647 W	12

Table 2. Normalized power for collective EV circuits.

From Table 1, it is the deduced that in charging stations for collective EV circuits all the installations are AC nature. Charging mode 4 is DC nature, but it requires an AC connection in order to permit the conversion from AC to DC. Therefore, all the *end* installations will be of AC nature. According to the ITC-BT-52, the mode 4 charging stations that are located in public stations like public parkings, need to be prepared for charging mode 3.

The possible points of connection and the type of power supply are detailed in Table **3**, reflecting the possible locations. This table has been constructed based on the information of ITC-BT-52. The electrical characteristics (current, voltage and powers) used for the different type of charging are depicted in Table 4.

Power supply of the charging station	Rated current at the point of connection	Charging mode	Possible location of the connection point
AC single-phase	10 A	1 or 2	No*
	10 A	1 or 2	No*
	16 A	3	Yes
	32 A	3	Yes
AC three-phase	16 A	3	Yes
	32 A	3	Yes
	63 A	3	Yes

* Permitted only for motorbikes and electric bikes.

Table 3. Possible points of connection to be installed depending on their location

Current (A)	Voltage (V)	Power (kW)
10	230	2,3
16	230	3,7
32	230	7,4
16	400	11
32	400	22
64	400	44
50	DC	50
50	DC	50

Table 4. Usual electrical characteristics for charging points

In ITC-BT-52, several connection schemes are considered for the connection of EVs to the charging station. However, according to the same ITC, they do not apply for the connection of charging stations that are fed by a grid independent of the AC distribution grid. It states that for those installations fed by a DC grid or AC railway supply, the designer will specify the connection scheme. Nevertheless, in those cases the electrical connection scheme 4b of the ITC-BT-52 can be used as basis.

4.4. Infrastructure design

According to Table 2, to take the maximum profit of the installation, when the charger stations are AC, they should be connected to a 3-phase system. Otherwise, the maximum number of circuits would be reduced. So, at the *end* side only 3-phase systems will be considered (discarding 1-phase systems). On the other hand, it is important to know that the input voltage of commercial DC chargers is of 3-phase 400 V_{AC} nature, and the voltage transformation occurs inside the charger. Hence, all options will consider the *end* side as a 3-phase 400 V_{AC}.

To avoid extra civil works and their associated costs, it will be preferred finding paths through the own installations. There can be different options to interconnect the railway electric network to the B:SM electric facilities depending on the *origin* and *end* of the installation as shown in Figure 4Figure 4.

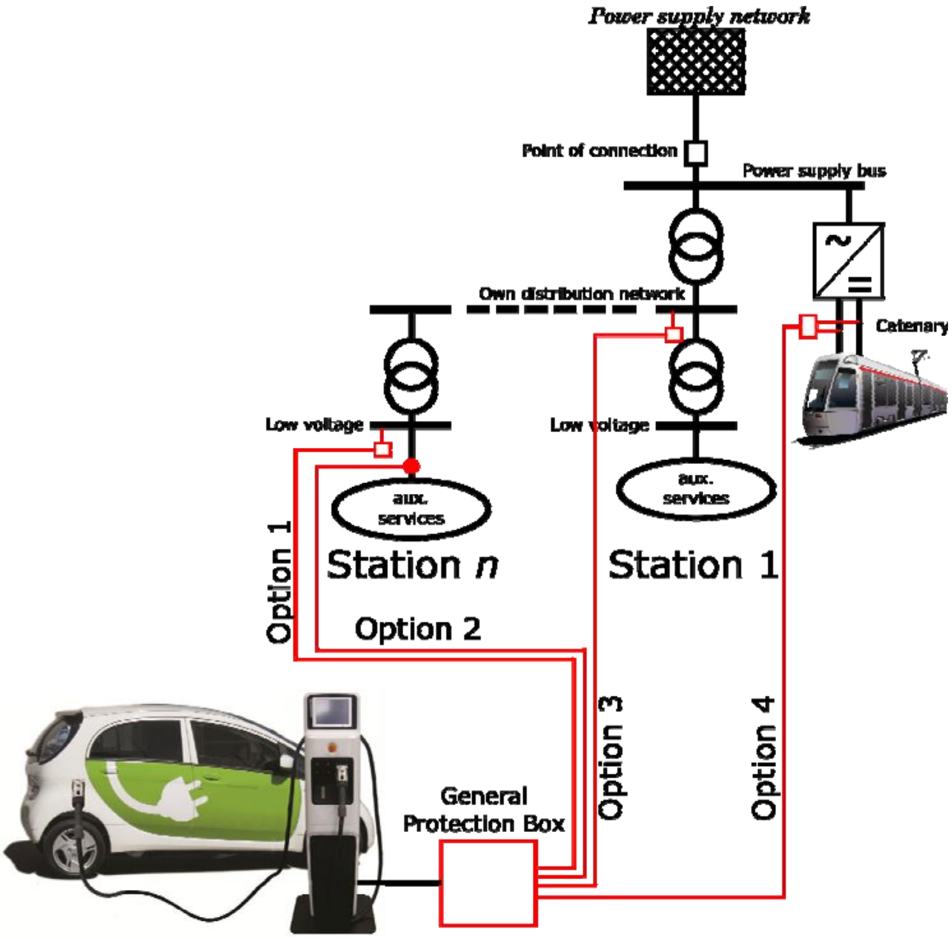


Figure 4. Different options to interconnect railway network to the EV charging stations. Source: Own elaboration

- Option 1: the *origin* is in the 3-phase LV_{AC} side with a dedicated line beginning at the bus bar used to feed auxiliary services. As it is a dedicated line, an additional protection will be required. In general, the installation will not require additional transformers or converters, as the *origin* and the *end* voltages are of the same rating and nature (3-phase 400 V_{AC}). For those installations having single-phase chargers, the 230 V_{AC} input will be required. This 230 V_{AC} will be obtained from phase-to neutral conductors.

  A special case will occur if the *origin* is the 3-phase 230 V_{AC} LV network of the underground. This network has no neutral wire. Hence, in this case the *end* installation can only have chargers of 1-phase 230 V_{AC}. If 3-phase 400 V_{AC} is desired, then a three-phase step up transformer 230 V_{AC}/400 V_{AC} will be required. This transformer will be delta-star, where the 400 V_{AC} side will have a neutral conductor for providing the possibility of feeding 1-phase EV chargers. If a transformer has to be installed (which is the case) it is worth doing it at the own distribution network bus (rated to 6 kV in the case of the underground), to avoid overloading the already existing downstream transformer.

  This new installation will increase the total consumption downstream of the HV-LV transformer. It will be required to avoid overloading of this power transformer. In addition, if this new infrastructure is installed at each station, it can be experienced a substantial load increase, being the possibility of overloading equipment upstream the HV-LV transformers. In this case, the upstream equipment should be replaced.

	Underground			**Tram**	**ADIF-RENFE**	**FGC**
Origin	3-phase 400 V_{AC}	3-phase 230 V_{AC}	3-phase 230 V_{AC}	Not enough input data	Not enough input data	Not enough input data
Cable	3-phase + neutral. Protected at the GPB	3-phase Protected at the GPB	3-phase + neutral. Protected at the GPB			
Power transformer	NO	NO	3-phase 230/400 V delta-star type			
End	3-phase 400 V_{AC} including neutral conductor	3-phase 230 V_{AC} without neutral. Can only feed 1-phase chargers	3-phase 400 V_{AC} including neutral conductor			

Table 5. Characteristics of the interconnection according to Option 1

- Option 2: the *origin* is in the 3-phase LV_{AC} side, specifically in a line which shares part of the existing cable that feeds the auxiliary devices. As it is a derivation, in principle, there is no need of installing an additional protection. Nevertheless, it must be taken into account, that the cable upstream has been designed for a specific power rating that it cannot be exceeded.

  As in Option 1, the installation will not need additional transformers or converters, as the *origin* and the *end* voltages are of the same rating and nature (3-phase 400 V_{AC}). For those installations having single-phase chargers, the 230 V_{AC} input will be required. This 230 V_{AC} will be obtained from phase-to neutral conductors.

  Again, similarly to Option 1, if the *origin* is the 3-phase 230 V_{AC} LV network, the *end* installation can only have chargers of 1-phase 230 V_{AC} (as this network has no neutral wire, for the case of the underground, at least).

  If a 3-phase 400 V_{AC} installation is needed at the *end*, then a three-phase step up transformer 230 V_{AC}/400 V_{AC} will be required. This transformer will be delta-star, where the 400 V_{AC} side will have a neutral conductor for providing the possibility of feeding 1-phase EV chargers.

  This new installation will also increase the total demand downstream of the HV-LV transformer, so this must be taken into account to avoid overloading the power transformer. If this new installation is replicated at each station, there will be a significant load increase in the installation. Therefore, the existing equipment upstream the HV-LV might need to be replaced so that the power ratings are the appropriate ones.

  Table 6 summarises the characteristics of the interconnection according to Option 2.

	Underground		**Tram**	**ADIF-RENFE**	**FGC**
Origin	3-phase 400 V_{AC}	3-phase 230 V_{AC}	Not enough input data	Not enough input data	Not enough input data
Cable	3-phase + neutral. Protected at the existing GPB	3-phase Protected at the existing GPB			
Power transformer	NO	NO			
End	3-phase 400 V_{AC} including neutral conductor	3-phase 230 V_{AC} without neutral. Can only feed 1-phase chargers			

Table 6. Characteristics of the interconnection according to Option 2

- Option 3: the *origin* is in the 3-phase HV_{AC} side, with a dedicated line. As it is a dedicated line, an additional protection will be required. In this case, the installation requires additional transformers. At the *origin* the supply is 3-phase HV_{AC} (6 kV for underground and either 6 kV or 11 kV for FGC), while at the *end* the needed voltage input is 3-phase LV_{AC} (400 V_{AC}), therefore, at least one step down transformer is required.

  This transformer could be located either at the *origin* or at the *end* of the cable feeding the EV charging point. If installed at the *origin,* the cable that feeds the EV charging point will be medium voltage one and the power transmission will have lower losses. If installed at the *end* the cable that feeds the EV charging point will be low voltage and the losses will be higher compared to the previous option.

  Similarly to Options 1 and 2, this new installation increases the total demand downstream of the HV transformer, so it is mandatory that this transformer has enough rating to withstand the existing demand before the new installation, plus the new load. If the transformer rating is not sufficient, a new step down transformer needs to be connected in parallel to the existing one. Table 7 summarises the characteristics of the interconnection according to Option 3.

	Underground		**Tram**	**ADIF-RENFE**	**FGC**	
Origin	3-phase 6 kV_{AC}	3-phase 6 kV_{AC}	Not enough input data	Not enough input data	3-phase 6 or 11 kV_{AC}	3-phase 6 or 11kV_{AC}
Cable	3-phase+neutral Protected at the GPB	3-phase Protected at the GPB			3-phase+neutral Protected at the GPB	3-phase Protected at the GPB
Power transformer	YES, at the origin	YES, at the end			YES, at the origin	YES, at the end
End	3-phase 400 V_{AC} including neutral conductor	3-phase 230 V_{AC} without neutral. Can only feed 1-phase chargers			3-phase 400 V_{AC} including neutral conductor	3-phase 230 V_{AC} without neutral. Can only feed 1-phase chargers

Table 7. Characteristics of the interconnection according to Option 3

- Option 4: The *origin* is in the catenary. To create the 3 phases plus neutral conductor needed at the *end* a voltage source converter (VSC) will be required with the grid forming capability. This converter can be installed near the catenary or in the EV parking side depending on the space availability. It will be preferred to install the inverter as close as possible to the parking side because the power losses and voltage drops are lower in DC systems than in AC. The DC power cable will be protected with the adequate devices according to the LV or HV standards respectively depending on the DC voltage rating (750 V_{DC} or 1.5 kV_{DC}). Table 8 summarises the characteristics of the interconnection according to Option 4. Depending on the sizing of the already existing AC/DC converter (and most probably, it has been sized according to the power rating of the DC lines of the catenary), this option is not feasible without its replacement or it will only be feasible if the catenary and EV charging point are never fed simultaneously. In addition, this option should consider that the catenary is feeding a train, which has periodic stops, and therefore, its consumption profile presents valleys (corresponding to null load during stops) and peaks (during the start up). Furthermore, this demand variations occur in the range of seconds and therefore limits the available power to feed the EV charging point. This power must be as constant as possible, otherwise it will lead to fast charges and discharges of the batteries of the EVs, increasing their cycling and accelerating their aging.

	Underground		**Tram**		**ADIF-RENFE**		**FGC**	
Origin	1.2-1.5 kV$_{DC}$	1.2-1.5 kV$_{DC}$	750 V$_{DC}$	750 V$_{DC}$	1.5 kV$_{DC}$; 3 kV$_{DC}$	1.5 kV$_{DC}$; 3 kV$_{DC}$	1.5 kV$_{DC}$	1.5 kV$_{DC}$
Power converter	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC	YES, AC/DC or DC/DC
Cable	AC 3-phase + neutral or DC	AC 3-phase + or DC	AC 3-phase + neutral or DC	AC 3-phase + neutral or DC	AC 3-phase + neutral or DC	AC 3-phase + neutral or DC	AC 3-phase + neutral or DC	AC 3-phase + neutral or DC
Power transformer	YES	YES	YES	YES	YES	YES	YES	YES
End	3-phase 400 V$_{AC}$ including neutral conductor	3-phase 230 V$_{AC}$ without neutral. Can only feed 1-phase chargers	3-phase 400 V$_{AC}$ including neutral conductor	3-phase 230 V$_{AC}$ without neutral. Can only feed 1-phase chargers	3-phase 400 V$_{AC}$ including neutral conductor	3-phase 230 V$_{AC}$ without neutral. Can only feed 1-phase chargers	3-phase 400 V$_{AC}$ including neutral conductor	3-phase 230 V$_{AC}$ without neutral. Can only feed 1-phase chargers

Table 8. Characteristics of the interconnection according to Option 4

Qualitative comparison of Options 1, 2, 3 and 4

Once all the possible options for connecting the railway station to the EV charging point have been generally described, a brief qualitative comparison is performed. Option 1 could seem the simplest one, as the voltage rating of the *origin* and *end* are the same. Option 2 is very similar to Option 1, but more complex from an electrical point of view. In Option 2 the line feeding auxiliary services needs to be modified and any problem affecting it will also disturb the line feeding the EV charging point. Furthermore, most probably, this line has been sized according to the load of the auxiliary services it feeds.

While Options 1,2 and 3 might need transformers to adapt the voltage ratings, none of them needs converters, because the *origin* and the *end* voltages are all of AC nature. However, Option 4 requires power electronics to adapt the DC nature of the line feeding the catenary to the AC nature of the EV charging point installation (or to the DC voltage required for fast charging). This will increase the cost significantly.

Another option to connect the railway infrastructure with the EV charging point (and which has not been shown in Figure 4), consists of locating the *origin* in a very high voltage bus (power supply bus of Figure 4). However, this implies the need of a transformer with stronger requirements, which occupies more space and will, enlarge the costs.

Taking into consideration of the above, Option 3 is in fact the only possible one according to Low Voltage Electrical Code and the Power System Law. Nevertheless, the requirements of Options 1 and 2 will be also analysed, in case there will be changes in current regulation.

4.5. *Technical and use parameters*

From the before explained options for linking the railway installation with the EV charging point, the options that will be analysed is Option 3 (as it is the only feasible one according to the norm), detailing all the needed equipment for monitoring, operation and protection purposes.

In Option 3, the line feeding the EV charging point can be a three-phase+neutral line of 400 V (if the voltage at the bus of the own distribution network is reduced installing a transformer in the *origin*) or can be a three-phase line of high voltage (6 kV or 11 kV, if the transformer is installed at B:SM facilities).

Independently of the voltage rating needed for the line that feeds the EV charging point, most of the following electrical equipment will be required: **cabling, earthing system, protection system, monitoring and metering**.

Cable sizing

The choice of the power rating of the cable built from the railway installation to the EV charging point needs to take into consideration:

- The own distribution network power capacity.
- The power to be delivered at the end, which will be on the range from 2.7 kW to 50 kW, as shown in Table 2.
- The maximum available power that could flow through the line to be built, based on the demand profile of the auxiliary services, measured at the *origin* of the installation.

With this information, the power rating of the cable/s of the new installation corresponds to the minimum between the power to be delivered at the end and the power that could flow through the line that feeds it, measured at its origin.

The current of the cable can be computed knowing the power rating and voltage rating. Then, the cross-section of the cable is determined based on its carrying current. All these calculations need to be done according to the Spanish Low Voltage Electrical Code (*Reglamento Electrotécnico de Baja Tensión, REBT2002*) for LV cables. The calculations need to take into consideration the *High Voltage Electrical Code (Reglamento de Líneas Eléctricas de Alta Tensión, LAT).*

The cross-section of the cable is typically calculated based on the criteria of:
- Maximum allowed current: in the worst conditions, the temperature of the insulating materials should not exceed the values specified by the norm. The maximum temperature is 70°C for thermoplastic and 90°C for thermostable (according to the UNE 20435) for LV cables.
- Maximum voltage drop: to supply the appropriate voltage to the recipients and to avoid excessive losses, the voltage drop must not exceed a maximum value imposed by the norm. It is a determining factor for long lines.
- Maximum shortcircuit current: the material must be able to withstand shorcircuit currents or overcurrents, which could last more than the time needed for protections to disconnect. This criterion is especially important for high voltage, since for selectivity reasons the protections are generally a bit slower than those of low voltage. This last criteria applies typically to HV cables, but not to LV ones, as in the latter case the mass of the cable is big enough respect to the energy involved that the temperature does not reach dangerous values during the time protections need to actuate.

The cross-section of the cable will be at least the minimum section that accomplishes all these criteria.

LV distribution installations, in case of crossing railway, need to accomplish the requirements specified in ITC-BT-07. It states that the cables need to be located inside protective tubes and following the requirements of ITC-BT-21. They need to be covered with concrete and be, when possible, perpendicular to the rail, with a minimum depth of 1.3 m respect to the lower part of the railway tie. Additionally, they need to overtake the rails in 1.5 m per side.

The section and number of conductors also need to take into account the following aspects:

- Maximum forecasted load according to ITC-BT-10 and maximum current intensity for the type of conductor and conditions of its installation.
- Supply voltage rating.
- Maximum voltage drop, which is the established by the distribution company for the voltage drop sharing in the grid elements so that in the general protection box, the voltage drop is consistent with what is required by the Electrical code.

In next paragraphs, the general guidelines to size LV cables according to the REBT2002 are detailed. The procedure to find the cable sections is the same for HV cables, but in the latter case the norm to be considered is the Guía ITC-LAT-06 (*Líneas subterráneas con cables aislados*).

Maximum current

The maximum forecasted power will affect the carrying current of the cable. The current needs to be computed according to Equation 1 for 3-phase installations:

$$I = \frac{S_{installation}}{\sqrt{3}\cdot U} = \frac{\sqrt{P^2+Q^2}}{\sqrt{3}\cdot U} = \frac{P}{\sqrt{3}\cdot U\cdot\cos\varphi} \qquad \text{(Equation 1)}$$

being $S_{installation}$ the maximum apparent power, P the maximum power, U the rated line voltage and $\cos\varphi$ the power factor.

Once this current I is known, the cable transmitting it needs to be sized for, at least, this current. The tables form ITC-BT-07 reflect the maximum admitted currents depending on:

- the type and depth of the installation
- the insulation of the cable
- the depth of the terrain installation
- the number of circuits
- the maximum temperature of operation
- terrain resistivity

In many cases, the maximum current determined through the tables needs to be adjusted using correction factors that take into account the effect of temperature variations, depth of the installation, terrain resistivity, etc.

Maximum voltage drop

For 3-phase AC systems, the method of calculating voltage drops based, knowing the power factor is used:

$$\Delta U \approx \sqrt{3}I(R\cos\varphi + X\sin\varphi) = \frac{P}{U}\left(R + X\tan\varphi\right) \qquad \text{(Equation 2)}$$

where I is the line full load or starting current (A), R is the AC resistance of the cable (Ohms), X is the AC reactance of the cable (Ohms) and U is the rated voltage of the cable.

If the reactance (X) of the cable is small enough and can be neglected, Equation 2 is simplified into:

$$\Delta U \approx \sqrt{3} I R \cos\varphi = \frac{P}{U} R \qquad \text{(Equation 3)}$$

The voltage drop, ΔU, cannot exceed the limits established by the Electrical Code applying.

The conductor resistance is dependent on the section of the conductor, its length (L), and the resistivity (ρ) of the material (typically copper or aluminium):

$$R = \rho \cdot \frac{L}{S} \qquad \text{(Equation 4)}$$

Replacing the expression of R from Equation 4 in Equation 3, next expression is obtained:

$$\Delta U \approx \sqrt{3}\, R\, I \cos\varphi = \frac{\sqrt{3}\,\rho\, L\, I \cos\varphi}{S} \qquad \text{(Equation 5)}$$

Equation 5 allows to find the voltage drop corresponding to section S. Alternatively, S can be isolated to determine which section ensures a maximum voltage drop specified $\Delta u_{\text{màx}}$ (in V, given by the norm):

$$\Delta U \approx \frac{\sqrt{3}\,\rho\, L\, I \cos\varphi}{S} = \frac{\rho\, L\, P}{S\, U} \quad \Rightarrow \quad S \geq \frac{\sqrt{3}\,\rho\, L\, I \cos\varphi}{\Delta u_{\text{màx}}} = \frac{\rho\, L\, P}{U\, \Delta u_{\text{màx}}}$$

The current for the cable being sized must be less or equal than the maximum admitted current and must be such that the voltage drop does not exceed the one required in the norm.

Based on these guidelines, cable sections for LV and HV installations must be selected according to the tables contained in the ITC-BT-07 and ITC-LAT-06, respectively. They include tables for different types of conductor configurations, insulators, installations.

An example of one of these tables in ITC-BT-07 is shown in Table **9**, where different possible normalized sections for copper conductors in underground installations are depicted. An example of one of these tables contained in ITC-LAT-06 is shown in Table 16, where different possible normalized sections are depicted depending on the resistivity of the terrain and on the disposition of the cables: underground versus underground and inside tube. The table is used to correct the maximum permitted intensity according to the terrain resistivity.

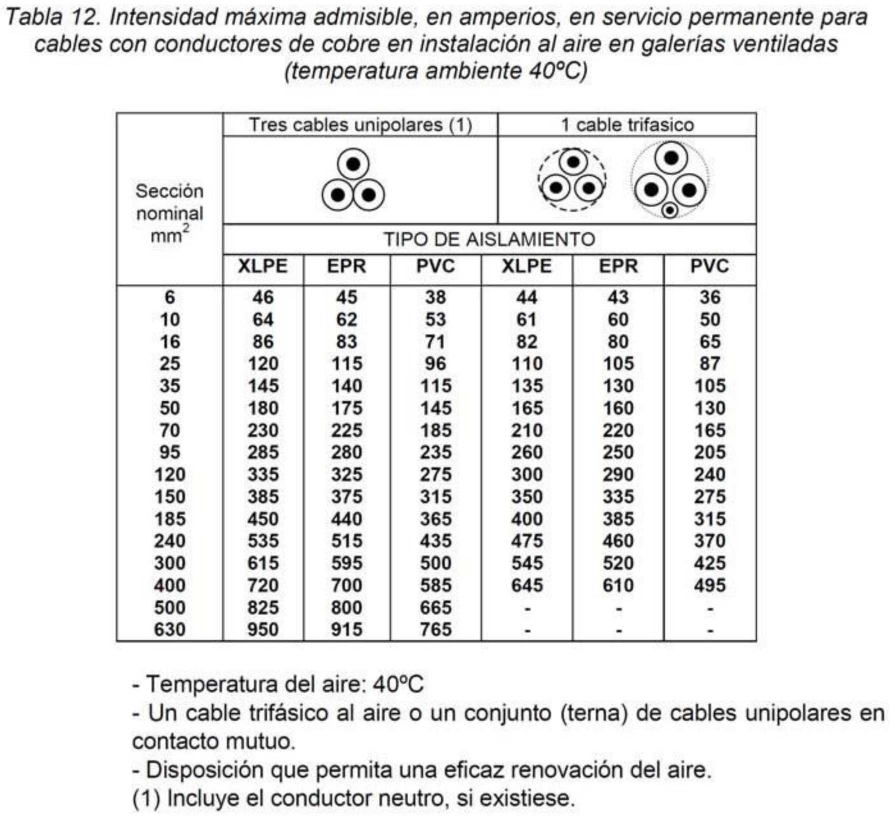


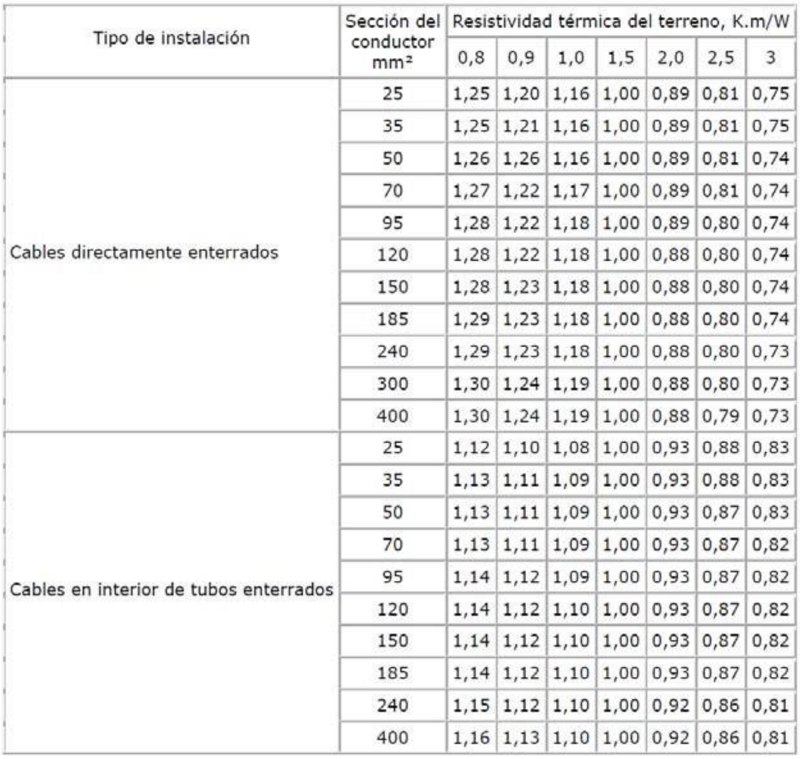
Tabla 12. Intensidad máxima admisible, en amperios, en servicio permanente para cables con conductores de cobre en instalación al aire en galerías ventiladas (temperatura ambiente 40ºC)

Sección nominal mm²	Tres cables unipolares (1)			1 cable trifasico		
	TIPO DE AISLAMIENTO					
	XLPE	**EPR**	**PVC**	**XLPE**	**EPR**	**PVC**
6	**46**	**45**	**38**	**44**	**43**	**36**
10	**64**	**62**	**53**	**61**	**60**	**50**
16	**86**	**83**	**71**	**82**	**80**	**65**
25	**120**	**115**	**96**	**110**	**105**	**87**
35	**145**	**140**	**115**	**135**	**130**	**105**
50	**180**	**175**	**145**	**165**	**160**	**130**
70	**230**	**225**	**185**	**210**	**220**	**165**
95	**285**	**280**	**235**	**260**	**250**	**205**
120	**335**	**325**	**275**	**300**	**290**	**240**
150	**385**	**375**	**315**	**350**	**335**	**275**
185	**450**	**440**	**365**	**400**	**385**	**315**
240	**535**	**515**	**435**	**475**	**460**	**370**
300	**615**	**595**	**500**	**545**	**520**	**425**
400	**720**	**700**	**585**	**645**	**610**	**495**
500	**825**	**800**	**665**	**-**	**-**	**-**
630	**950**	**915**	**765**	**-**	**-**	**-**

- Temperatura del aire: 40ºC
- Un cable trifásico al aire o un conjunto (terna) de cables unipolares en contacto mutuo.
- Disposición que permita una eficaz renovación del aire.

(1) Incluye el conductor neutro, si existiese.

Table 9. Example of cable sections from ITC-BT-07. Source: ITC-BT-07



Tipo de instalación	Sección del conductor mm²	Resistividad térmica del terreno, K.m/W						
		0,8	0,9	1,0	1,5	2,0	2,5	3
Cables directamente enterrados	25	1,25	1,20	1,16	1,00	0,89	0,81	0,75
	35	1,25	1,21	1,16	1,00	0,89	0,81	0,75
	50	1,26	1,26	1,16	1,00	0,89	0,81	0,74
	70	1,27	1,22	1,17	1,00	0,89	0,81	0,74
	95	1,28	1,22	1,18	1,00	0,89	0,80	0,74
	120	1,28	1,22	1,18	1,00	0,88	0,80	0,74
	150	1,28	1,23	1,18	1,00	0,88	0,80	0,74
	185	1,29	1,23	1,18	1,00	0,88	0,80	0,74
	240	1,29	1,23	1,18	1,00	0,88	0,80	0,73
	300	1,30	1,24	1,19	1,00	0,88	0,80	0,73
	400	1,30	1,24	1,19	1,00	0,88	0,79	0,73
Cables en interior de tubos enterrados	25	1,12	1,10	1,08	1,00	0,93	0,88	0,83
	35	1,13	1,11	1,09	1,00	0,93	0,88	0,83
	50	1,13	1,11	1,09	1,00	0,93	0,87	0,83
	70	1,13	1,11	1,09	1,00	0,93	0,87	0,82
	95	1,14	1,12	1,09	1,00	0,93	0,87	0,82
	120	1,14	1,12	1,10	1,00	0,93	0,87	0,82
	150	1,14	1,12	1,10	1,00	0,93	0,87	0,82
	185	1,14	1,12	1,10	1,00	0,93	0,87	0,82
	240	1,15	1,12	1,10	1,00	0,92	0,86	0,81
	400	1,16	1,13	1,10	1,00	0,92	0,86	0,81

Table 10. Example of cable sections from Guía ITC-LAT-06. Source: ITC-LAT-06

Earthing system

In the case that the transmission of the electrical energy from the railway station to the EV charging point is performed using LV cables, the neutral conductor must be connected to ground at the transformation centre in the low voltage side. In addition, each 500 m it will require an additional ground connection (ITC-BT-07). This connection will be performed according to the ITC-BT-18 of the REBT2002.

If the transmission is performed using HV cables, any part of the installation that normally is supposed to be under no voltage, needs to be grounded (for instance, the shield of the power cables), according to the ITC-LAT-13.

Protection system

The transformation centre will be protected at the high and at the low voltage side according to [9] (Spanish Standard *Reglamento sobre condiciones técnicas y garantías de seguridad en instalaciones eléctricas de alta tensión*).

As shown in Figure 5 and Figure 6, a General Protection Box including a set of fuses (one per phase, but never for the neutral conductor) will protect the general power supply line against short circuit currents. These fuses must be capable to leave the line opened after an eventual fault before the power cable reaches 70 ºC or 90 ºC, depending on the cable insulation. So, both the maximum shortcircuit (avoiding permanent faults) and the minimum shortcircuit currents (ensuring opening the circuit before reaching the maximum temperature) have to be considered.

Then, a switch (Standard UNE-EN 60947-3) must be installed in the case that the general power supply line feeds more than 2 meters (more than two individual branches). This switch must be capable of being anchored in an opened position.

Additionally, each individual branch will require its own protection. This protection will be again performed by fuses (only the active phases). These fuses will be determined following the same criterion as the one used for the upstream fuses. But in this case, the response time must be faster in order to ensure that a downstream fault does not affect the fuse that protects the general power supply line. In the particular case of Figure 7, where one transformation centre feeds a single consumer, the Spanish Code permits to avoid the switch and to use just one fuse.

Once analysed all the needed equipment (cabling, earthing and protections), the feasibility of the different connection options is analysed.

Currently, the internal grid of the underground, tram, FCG is a private network. Thus, it must comply with the associated standards. But to distribute energy to different users, this private network shall turn to a distribution network, accomplishing with additional requirements. The following section describes the different options considering the underground becomes an electric distribution company and B:SM is a customer.

After analysing the Spanish Low Voltage Electrical Code, and knowing the Power System Law, all considered options are not currently permitted. Nevertheless, if the owner of the railway electric infrastructure becomes a distributor agent charging manager, it could be possible.

Option 1

Option 1a) From the legacy framework, to deliver electricity to a third party it is necessary to become a distributor agent. So, and according to the ITC-BT-12 of the REBT2002, the consumers must connect to a distribution grid through a specified protection scheme. Figure 5 shows this scheme. Downstream the transformer, the first element will be the general protection box (GPB), which will be in charge of protecting the general power supply line through adequate fuses. After the GPB, a general maneuver switch (IGM) is required. This switch is in charge, in case of necessity, to turn the metering system out of service. After that, for each third party to be supplied, a fuse and the metering system will be placed. The fuse prevents affecting the neighbours of one consumer in case of short-circuit. Hence the protection coordination will be required with the upstream protection systems. Then, the power cable can be installed to feed the costumer general protection and maneuver box. Where the power control switch, the residual current switch and the magneto-thermic switches will be installed.

This option requires the installation of the new power line and to adapt the current line protection devices. This case could be compliant with the Technical Code REBT2002.

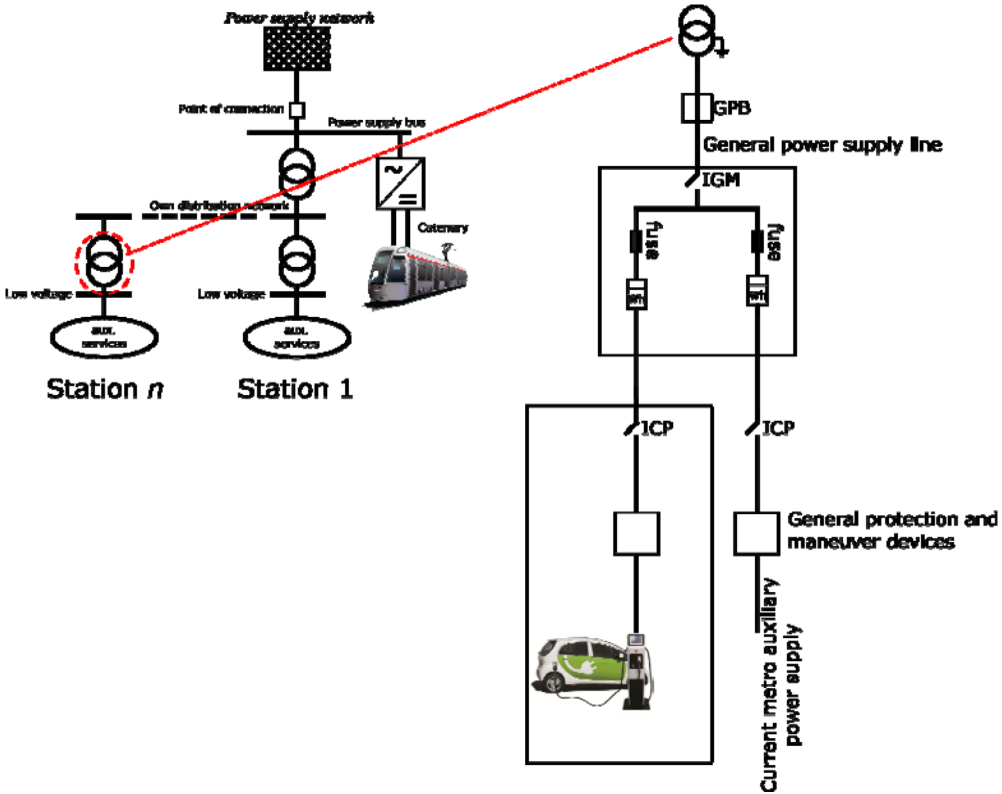


Figure 5. Interconnection layout for Option 1 modifying the current underground auxiliary power supply protection. Source: Own elaboration

Option 1b) The second possibility is shown in Figure 6. In this solution, the current power supply line of the auxiliary services should not be modified and only the new line and its protection should installed. It has the advantage that it is not required modifying the current installation, but in contrast, it would not be compliant with the Electrical Code REBT2002.

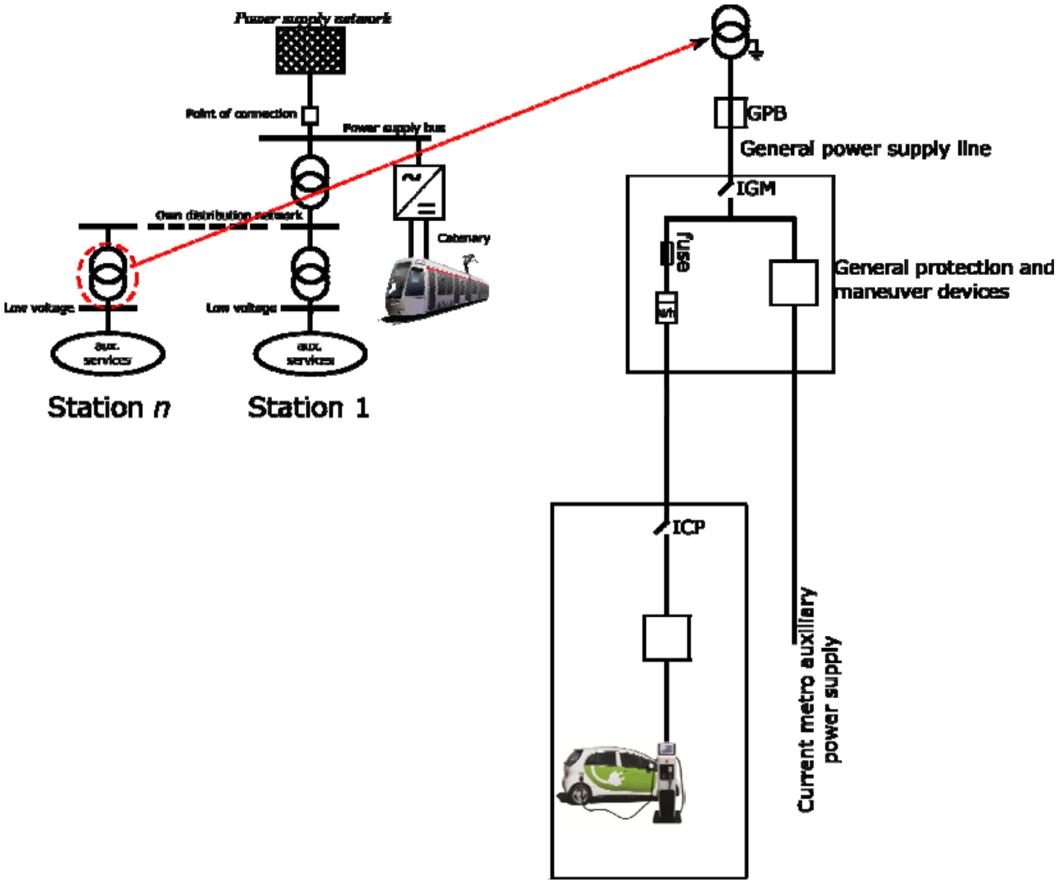


Figure 6. Interconnection layout for Option 1 without modifying the current underground auxiliary power supply protection. Source: Own elaboration

Options 1a and 1b are only considered for the case that the low voltage side of the transformer is three-phase 400 V_{AC} (with neutral conductor). In the case of having 230 V_{AC} three-phase system at the low voltage side, this option is not recommended due to the limitations explained before.

These options are not recommended due to the fact that the infrastructure is used for different functionalities: own consumption and distribution. Boundaries of each agent have to be clearly identified. This is a requirement according to the current regulation.

Option 2

The aim to consider this option was to avoid an amount of cable installation until the transformation centre. In fact, this solution is compliant with the Electrical Code REBT2002. Considering that the power transformer owner is a distributor, the ITC-BT-12 from the REBT2002 states that different users has to be fed with a dedicated line from the distributor. In addition, a part from the technical constraints of the option 1, its available power is not only limited but the power transformer available power but also by the upstream cable rating. Hence this option is also discarded.

Option 3

This option is similar to the option 1, but instead of sharing the transformation centre with the underground auxiliary services network, there is a dedicated transformation centre for feeding the EV facilities. The new installation is similar to option 1, but as there is only a single branch, the protection system is much simpler. The diference with respect to option 1 is that in option 3 a new transformation centre must be installed (see Figure 7). It will provide two main advantages respect to the previous options. First, the electric insulation thanks to the dedicated transformer will prevent any fault to be transferred to the rest of the network and second, the available power will depend only on the new design and on the capacity of the own distribution network. So, it can be designed taking into account the scalability and the future growth on the EV power demand.

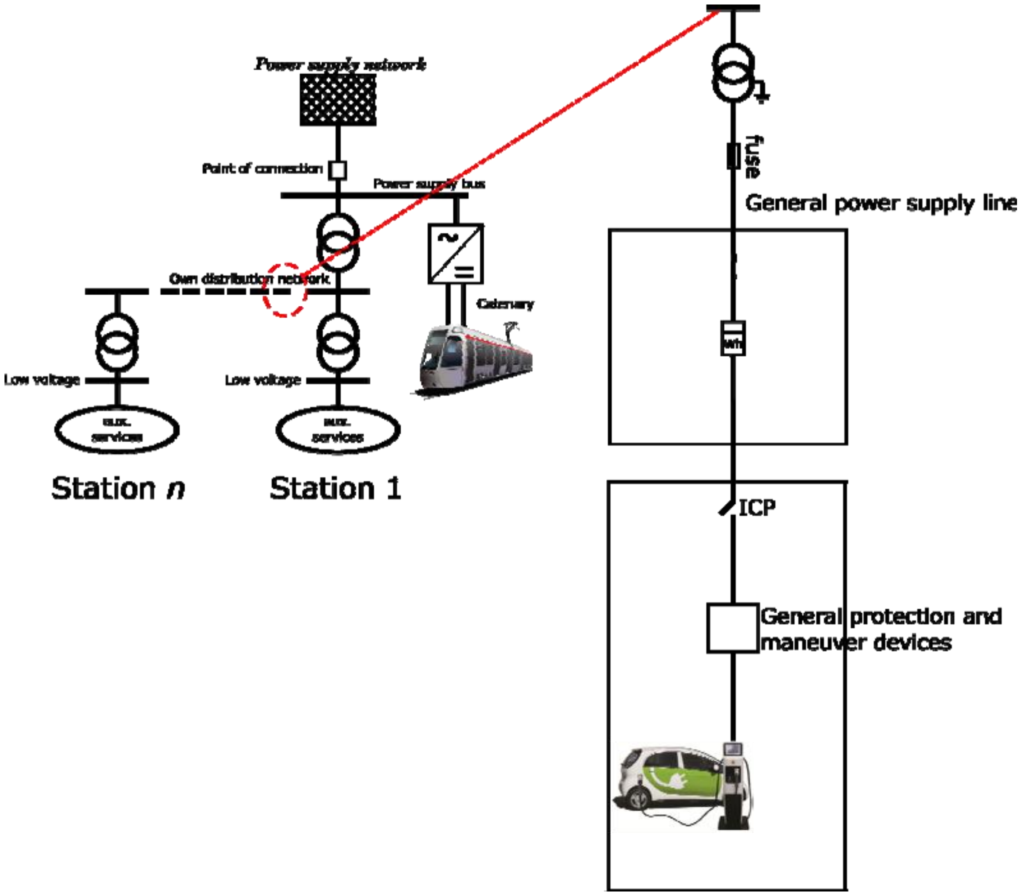


Figure 7. Interconnection layout for Option 3. Source: Own elaboration

4.6. Infrastructure operations and maintenance models

The periodicity and type of maintenance required in the infrastructure needed for connecting the railway station with the EV charging point depends on the type of installation. The actions to be performed in LV installations are specified in ITC-BT-05, while the actions required in HV installations are detailed in the “*Guía de la Instrucción Técnica Complementaria ITC- LAT 05”* and ITC-RAT-23 “*Instrucción Técnica Complementaria: verificaciones e inspecciones”.*

Regarding LV installations, as in this study they correspond to public facilities, following the ITC-BT-05, they require initial verifications according to UNE 20.460-6-61 and inspections once the installations have been executed, enlarged or modified and prior to the moment they give documentary evidence to the corresponding supervising official body. Furthermore, they will require periodic inspections every 5 years. These inspections are performed by the Control Institution.

As a result of the revision, the Control Institution will issue a certificate reflecting all the identification data of the installation, the list of defects and the qualification of the installation. The ITC-BT-05 specifies the type of defects and qualifcation of the installations. The defects identified in this certificate will need to be solved in less than 6 months. If the defects are detected at the initial inspection, the installation cannot be commissioned before solving them.

Regarding HV installations (which include the HV cables and transformation centres) the maintenance requirements specified in Guía Técnica de Aplicación de la ITC-RAT-23 include the following verifications before the commissioning of the installation:

a) Measuring step and contact voltages
b) Verification of the insulation distances
c) Visual verification and functional tests of the equipment
d) Functional tests of protection relays
e) Verification of the existence of the single line diagram of the installation and guides with the instructions of operation and maintenance of the equipment

Then, periodic verifications must be done at least once every 3 years. These verifications also include the visual inspection and measurement of the earthing system. As a result a certificate identifying the defects, which will be required to be solved before the date indicated, which has be before 6 months.

In addition to verifications (that may be performed by the owner of the installation), the supervising official body can perform inspections according to the actual legal framework.

4.7. Infrastructure performance specifications

The new infrastructure requires energy from an existing infrastructure, which feeds already railway consumptions, to supply energy to EV charging points. In order to guarantee a proper performance of the existing and the new infrastructure, a monitoring and control system is required.

EV user requests will be known through charging points, which uses OCCP protocol to send and receive commands. B:SM is currently done this at its Charging Control Center.

However, as it has been mentioned previously, power available at the new infrastructure is limited to the size of the cable and the current consumption of railway. Then, monitoring the electrical parameters (voltage, current and power) at the origin of new infrastructure is needed. With this data, plus the data collected by B:SM Charging Control Center will allow a proper performance of the new infrastructure.

4.8. Cost drivers

Here, the construction costs of the new infrastructure are analysed. This study pretends to provide an estimated cost of the different devices according to the options described previously and their deployment. Such estimated cost of the installation are assessed according to the power delivered to the charging station and the length of wiring that must be installed.

From the basis of the scheme of the elements that are required, it is possible to divide the installation in three parts; the transformer, the wiring and the General Protection Box (also known as CGP in Spanish).

These three parts are analysed in the next points, where at each part the cost of the equipment and the mounting is specified. These costs have been acquired from the ITEC database [8], which is updated yearly with data from Barcelona. Concretely, most part of the data come from the AMB (Àrea Metropolitana de Barcelona) database, which is the institution that manages the railway services. These databases have been selected in order to be as accurate as possible, because the projects which provide the data are similar to the one that is proposed.

In the *Transformer station* section the costs of the transformer, protections (high and low voltage) costs are specified, including the cost of installation. As an approach, some costs of transformation buildings are given. These costs give only a magnitude order of the price, but may differ considerably depending on each particular case.

In the *Wiring* section, the costs of low voltage and high voltage wires are given. Also the prices of the pipes and the excavations required. All these items per meter and with the installation costs.

Finally, in the *General Electrical Protection Box* section the costs of this item, fuses and double isolation box costs are given.

Transformer station

It is supposed that another transformer station already exists, which delivers low voltage power to other clients. It is assumed that there is enough space in this station to fit another transformer for the new infrastructure. The costs of setting-up the transformer station and protection are specified in Table 11.

Item	**Units**	**Cost**
Transformador trifàsic reductor de tensió (MT/BT) construït d'acord amb UNE-EN 60076 i UNE 21428, dielèctric oli d'acord amb UNE 21320, 250 kVA de potència, tensió assignada 24 kV, tensió primari 20 kV, tensió de sortida 420 V entre fases en buit o de 230/420 V entre fases en buit, freqüència 50 Hz, grup de connexió Dyn 11, regulació al primari +/- 2,5%, +/- 5%, +/- 10%, protecció pròpia del transformador amb termòmetre, per instal·lació interior o exterior, cisterna d'aletes, refrigeració natural (ONAN), commutador de regulació maniobrable sense tensió, passatapes MT de porcellana, passabarres BT de porcellana, 2 terminals de terra, dispositiu de buidat i presa de mostres, dispositiu d'ompliment, placa de característiques i placa de seguretat e instruccions de servei, col·locat. (Ref: ITEC FGG11180) Three-phase transformer, voltage reducer (MT / LT) built according UNE-EN 60076 and EN 21428, dielectric oil according to UNE 21320, 250 kVA power, 36 kV tension, 25 kV primary voltage, output voltage 400 V between phases, frequency 50 Hz. Connection Dyn 11, primary regulation +/- 2.5% +/- 5%, +/- 10 %. Thermometer for auto protection, indoor or outdoor installation, tank with fins, natural cooling (ONAN), switch for manoeuvre without tension, two ground terminals, emptying device and sampling device, nameplate and security and service instructions, placed and installed (Ref: ITEC FGG11180)	€/u	6036,77
Transformador trifàsic reductor de tensió (MT/BT) construït d'acord amb UNE-EN 60076 i UNE 60726, dielèctric sec encapsulat, 250 kVA de potència, tensió assignada 24 kV, tensió primari 20 kV, tensió de sortida 420 V entre fases en buit o de 230/420 V entre fases en buit, freqüència 50 Hz, grup de connexió Dyn 11, regulació al primari +/- 2,5%, +/- 5%, +/- 10%, protecció pròpia del transformador amb central electrònica d’alarmes, per instal·lació interior, refrigeració natural, placa de característiques i placa de seguretat e instruccions de servei, col·locat. (Ref: EGG13180) Three-phase transformer, voltage reducer (MT / LT) built according UNE-EN 60076 and EN 60726, dry dielectric encapsulated, 250 kVA power, 36 kV	€/u	7614,77

tension, 25 kV primary voltage, output voltage 400 V between phases, frequency 50 Hz. Connection Dyn 11, primary regulation +/- 2.5% +/- 5%, +/- 10 %. Electronical alarm central for auto protection, indoor installation, natural cooling, nameplate and security and service instructions, placed and installed.(Ref: EGG13180)		
Conjunt d’accessoris de seguretat i maniobra constituït per una banqueta aïllant, un extintor d’eficàcia 89B, guants aïllants, perxa aïllant i armari de primers auxilis, segons Instruccions Tècniques complementàries del Reglament sobre Condicions Tècniques i Garanties de Seguretat en Centrals Elèctriques, Subestacions i Centres de Transformació. B:O:E: 25-10-84, col·locat(Ref: BGJZ1000) Set of safety and manoeuvre accessories, made of an insulated bench, an 89B effectiveness fire extinguisher, insulating gloves, insulating pole and first aid cabinet, according to B.O.E: 25-10-84, mounted. (Ref: BGJZ1000)	€/u	444,10

Table 11: Costs of the transformer station

Depending on the power delivered to the EV charging points, the correct wire cross-section and proper protections for the maximum current that the wires can handle is choosen. The Table 12 contains the protections that must be installed in the low voltage side:

Item	Units	Cost
Interruptor automàtic magnetotèrmic de 25 A d'intensitat nominal, tipus ICP-M, tetrapolar (4P), de 6000 A de poder de tall segons UNE 20317, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN (Ref: EG4114JD) Circuit breaker of rated intensity 25 A, type ICP-M, 4 poles, 6000 A power cut according to UNE 20 317, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG4114JD)	€/u	77,44
Interruptor automàtic magnetotèrmic de 30 A d'intensitat nominal, tipus ICP-M, tetrapolar (4P), de 6000 A de poder de tall segons UNE 20317, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN (Ref: EG4114JE) Circuit breaker of rated intensity 30 A, type ICP-M, 4 poles, 6000 A power cut according to UNE 20 317, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG4114JE)	€/u	81,46
Interruptor automàtic magnetotèrmic de 40 A d'intensitat nominal, tipus ICP-M, tetrapolar (4P), de 6000 A de poder de tall segons UNE 20317, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG4114JH) Circuit breaker of rated intensity 40 A, type ICP-M, 4 poles, 6000 A power cut according to UNE 20 317, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG4114JH)	€/u	92,84
Interruptor automàtic magnetotèrmic de 50 A d'intensitat nominal, tipus ICP-M, tetrapolar (4P), de 6000 A de poder de tall segons UNE 20317, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG4114JJ) Circuit breaker of rated intensity 50 A, type ICP-M, 4 poles, 6000 A power cut according to UNE 20 317, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG4114JJ)	€/u	170,25
Interruptor automàtic magnetotèrmic de 63 A d'intensitat nominal, tipus ICP-M, tetrapolar (4P), de 6000 A de poder de tall segons UNE 20317, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG4114JK) Circuit breaker of rated intensity 63 A, type ICP-M, 4 poles, 6000 A power cut according to UNE 20 317, 4x18 mm DIN modules wide, mounted on DIN	€/u	176,57

profile. (Ref: EG4114JK)		
Interruptor automàtic magnetotèrmic de 25 A d'intensitat nominal, tipus PIA corba C, tetrapolar (4P), de 6000 A de poder de tall segons UNE-EN 60898, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG415AJD) Circuit breaker of rated intensity 25 A, type PIA curve C, 4 poles, 6000 A power cut according to UNE 60898, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG415AJD)	€/u	68,51
Interruptor automàtic magnetotèrmic de 32 A d'intensitat nominal, tipus PIA corba C, tetrapolar (4P), de 6000 A de poder de tall segons UNE-EN 60898, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG415AJF) Circuit breaker of rated intensity 32 A, type PIA curve C, 4 poles, 6000 A power cut according to UNE 60898, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG415AJF)	€/u	70,99
Interruptor automàtic magnetotèrmic de 40 A d'intensitat nominal, tipus PIA corba C, tetrapolar (4P), de 6000 A de poder de tall segons UNE-EN 60898, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG415AJH) Circuit breaker of rated intensity 40 A, type PIA curve C, 4 poles, 6000 A power cut according to UNE 60898, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG415AJH)	€/u	80,96
Interruptor automàtic magnetotèrmic de 50 A d'intensitat nominal, tipus PIA corba C, tetrapolar (4P), de 6000 A de poder de tall segons UNE-EN 60898, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG415AJJ) Circuit breaker of rated intensity 50 A, type PIA curve C, 4 poles, 6000 A power cut according to UNE 60898, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG415AJJ)	€/u	169,71
Interruptor automàtic magnetotèrmic de 63 A d'intensitat nominal, tipus PIA corba C, tetrapolar (4P), de 6000 A de poder de tall segons UNE-EN 60898, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG415AJK) Circuit breaker of rated intensity 63 A, type PIA curve C, 4 poles, 6000 A power cut according to UNE 60898, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG415AJK)	€/u	179,25
Interruptor diferencial de la classe AC, gamma terciari, de 40 A d'intensitat nominal, tetrapolar (4P), de sensibilitat 0,03 A, de desconnexió fix instantani, amb botó de test incorporat i indicador mecànic de defecte, construït segons les especificacions de la norma UNE-EN 61008-1, de 4 mòduls DIN de 18 mm d'amplària, muntat en perfil DIN. (Ref: EG4242JH) Differential switch of rated intensity 40 A, type AC third class, 4 poles, 0,03 A sensibility, fixed instantaneous disconnection, test button included with mechanical indicator, following the UNE EN 61008-1 rule, 4x18 mm DIN modules wide, mounted on DIN profile. (Ref: EG4242JH)	€/u	170,44

Table 12. Low voltage protections and installation costs

Some protections also have to be installed in the high voltage part. Some of these protections for 24 kV are shown in Table 13:

Item	**Units**	**Cost**
Cel·la de remunt, tensió assignada 24 kV, de tipus modular, amb barres, envoltant de xapa d’acer galvanitzat, captadors capacitius per a la detecció de tensió i sistema d’alarma sonora de posada a terra, col·locada. (Ref: EGH11400)	€/u	1398,56

Rising to busbar cubicle, 24 kV rated voltage, modular, with busbar, with galvanized steel cover, with capacitive collectors for voltage detection and acoustic alarm system with protective earth, installed. (Ref: EGH11400)		
Cel·la de protecció del transformador amb fusibles, tensió assignada 24 kV, de tipus modular, envoltant de xapa d’acer galvanitzat, tall i aïllament íntegre en SF6, intensitat nominal de 400 A/ 16 kVA, amb interruptor-seccionador rotatiu tripolar de 3 posicions (connectat, seccionat, posada a terra) amb comandament manual combinat amb fusibles freds, captadors capacitius per a la detecció de tensió i sistema d’alarma sonora de posada a terra, col·locada. (Ref: EGH74214) Protection cubicle with fuses, 24 kV rated voltage, modular, with busbar, with galvanized steel cover, power cut and isolation with SF6, 400 A rated current in 16 kVA, rotational isolator switch with 3 positions (connected, isolated, connected to the ground), with manual control and cold fuses control, capacitive collectors for voltage detection and acoustic alarm system with protective earth, installed. (Ref: EGH74214)	€/u	3694,56
Cel·la de protecció del general amb fusibles i relé, amb tensió assignada 24 kV, de tipus modular, envoltant de xapa d’acer galvanitzat, tall i aïllament íntegre en SF6, intensitat nominal de 400 A/ 16 kVA, amb interruptor-seccionador rotatiu tripolar de 3 posicions (connectat, seccionat, posada a terra) amb comandament manual combinat amb fusibles freds, captadors capacitius per a la detecció de tensió i sistema d’alarma sonora de posada a terra, col·locada. (Ref: EGH44314) Protection cubicle of the general with fuses and relay, 24 kV rated voltage, modular, with busbar, with galvanized steel cover, power cut and isolation with SF6, 400 A rated current in 16 kVA, rotational isolator switch with 3 positions (connected, isolated, connected to the ground), with manual control and cold fuses control, capacitive collectors for voltage detection and acoustic alarm system with protective earth, installed. (Ref: EGH44314)	€/u	5529,56

Table 13. High voltage protections and installation costs

In case that there is not a place for the transformer, then the costs of the construction of the required space must be considered. These costs are highly variable and hard difficult to assess. Although each case requires a particular analysis, values of Table 14 can be taken as an approach.

Item	Units	Cost
Edifici prefabricat de formigó armat (estructura monobloc) i execució compacta, per a centre de transformació de superfície i maniobra interior, tensió assignada de 24 kV, amb 2 portes (1 vianants i 1 transformador), amb enllumenat connectat i governat des del quadre de BT, ventilació natural, per a 1 transformador de 1000 kVA de potència. (Ref: EGJ14111) Concrete prefabricated building (mono block structure) and compact execution for transformation centre and interior manoeuvre. 24 kV rated voltage, with two doors (one for pedestrian and one for the transformer) with lighting connected and governed from the low voltage box, natural ventilation, for a 1000 kVA power transformer. (Ref: EGJ14111)	€/u	7742,60
Edifici prefabricat de formigó armat (estructura monobloc), per a centre de transformació de superfície i maniobra interior, tensió assignada de 24 kV, amb 2 portes (1 vianants i 1 transformador), amb enllumenat connectat i governat des del quadre de BT, ventilació natural, per a 1 transformador de 1000 kVA de potència. (Ref: EGJ14112) Concrete prefabricated building (mono block structure) for transformation centre and interior manoeuvre. 24 kV rated voltage, with two doors (one for pedestrian and one for the transformer) with lighting connected and governed from the low voltage box, natural ventilation, for a 1000 kVA power	€/u	9855,60

transformer. (Ref: EGJ14112)		
Edifici prefabricat de formigó armat (estructura monobloc), per a centre de transformació de soterrat i maniobra interior, tensió assignada de 36 kV, amb 2 accessos (1 vianants i 1 transformador), amb enllumenat connectat i governat des del quadre de BT, ventilació natural, per a 1 transformador de 1000 kVA de potència. (Ref: EGJ26110) Concrete prefabricated building (mono block structure) for underground transformation centre and interior manoeuvre. 24 kV rated voltage, with two entries (one for pedestrian and one for the transformer) with lighting connected and governed from the low voltage box, natural ventilation, for a 1000 kVA power transformer. (Ref: EGJ26110)	€/u	26002,60

Table 14. Transformation buildings costs

Wiring

The cross-section of the cables is calculated as has been described previously. The wire and installation costs into a tube per meter appear in the Table 15:

Item	Units	Cost
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RVFV, tetrapolar, de secció 4 x 10 mm2, amb armadura de fleix d'acer i coberta del cable de PVC, col·locat en tub. (Ref: EG31H564) Copper conductor cable with 0.6 / 1 kV assigned voltage, RVFV designation, 4 poles, 4 x 10 mm2 sections with steel armour, PVC cover, mounted into pipe. (Ref: EG31H564)	€/m	3,73
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RVFV, tetrapolar, de secció 4 x 16 mm2, amb armadura de fleix d'acer i coberta del cable de PVC, col·locat en tub. (Ref: EG31H574) Copper conductor cable with 0.6 / 1 kV assigned voltage, RVFV designation, 4 poles, 4 x 16 mm2 sections with steel armour, PVC cover, mounted into pipe. (Ref: EG31H574)	€/m	6,42
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RVFV, tetrapolar, de secció 4 x 25 mm2, amb armadura de fleix d'acer i coberta del cable de PVC, col·locat en tub. (Ref: EG31H584) Copper conductor cable with 0.6 / 1 kV assigned voltage, RVFV designation, 4 poles, 4 x 25 mm2 sections with steel armour, PVC cover, mounted into pipe. (Ref: EG31H584)	€/m	8,30
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RVFV, tetrapolar, de secció 4 x 35 mm2, amb armadura de fleix d'acer i coberta del cable de PVC, col·locat en tub. (Ref: EG31H594) Copper conductor cable with 0.6 / 1 kV assigned voltage, RVFV designation, 4 poles, 4 x 35 mm2 sections with steel armour, PVC cover, mounted into pipe. (Ref: EG31H594)	€/m	10,29
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RVFV, tetrapolar, de secció 4 x 50 mm2, amb armadura de fleix d'acer i coberta del cable de PVC, col·locat en tub. (Ref: EG31H5A4) Copper conductor cable with 0.6 / 1 kV assigned voltage, RVFV designation, 4 poles, 4 x 50 mm2 sections with steel armour, PVC cover, mounted into pipe. (Ref: EG31H5A4)	€/m	12,51
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RZ1-K (AS),	€/m	40,16

tetrapolar, de secció 4 x 70 mm2, amb coberta del cable de poliolefines amb baixa emissió de fums, col·locat en tub. (Ref: EG3125B4) Copper conductor cable with 0.6 / 1 kV assigned voltage, RZ1-K designation, 4 poles, 4 x 70 mm2 sections, polyolefin cover with low smoke emissions, mounted into pipe. (Ref: EG3125B4)		
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RZ1-K (AS), tetrapolar, de secció 4 x 95 mm2, amb coberta del cable de poliolefines amb baixa emissió de fums, col·locat en tub. (Ref: EG3125C4) Copper conductor cable with 0.6 / 1 kV assigned voltage, RZ1-K designation, 4 poles, 4 x 95 mm2 sections, polyolefin cover with low smoke emissions, mounted into pipe. (Ref: EG3125C4)	€/m	51,52
Cable amb conductor de coure de 0,6/1 kV de tensió assignada, amb designació RZ1-K (AS), tetrapolar, de secció 4 x 120 mm2, amb coberta del cable de poliolefines amb baixa emissió de fums, col·locat en tub. (Ref: EG3125D4) Copper conductor cable with 0.6 / 1 kV assigned voltage, RZ1-K designation, 4 poles, 4 x 120 mm2 sections, polyolefin cover with low smoke emissions, mounted into pipe. (Ref: EG3125D4)	€/m	65,36

Table 15: Costs of wire and installation per meter

In the Table 16 appear the costs of tube and montage for surface mounting:

Item	**Units**	**Cost**
Tub rígid de PVC, de 32 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 2 J, resistència a compressió de 1250 N i una rigidesa dielèctrica de 2000 V, amb unió roscada i muntat superficialment. (Ref: EG21291H) Rigid PVC pipe, 32 mm rated diameter, insulator and flame non-propagator, impact resistance of 2 J, 1250 N compression resistance and 2000 V dielectric strength, with threaded union and surface mounted. (Ref: EG21291H)	€/m	3,84
Tub rígid de PVC, de 40 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 2 J, resistència a compressió de 1250 N i una rigidesa dielèctrica de 2000 V, amb unió roscada i muntat superficialment. (Ref: EG212A1H) Rigid PVC pipe, 40 mm rated diameter, insulator and flame non-propagator, impact resistance of 2 J, 1250 N compression resistance and 2000 V dielectric strength, with threaded union and surface mounted. (Ref: EG212A1H)	€/m	4,68
Tub rígid de PVC, de 50 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 2 J, resistència a compressió de 1250 N i una rigidesa dielèctrica de 2000 V, amb unió roscada i muntat superficialment. (Ref: EG212B1H) Rigid PVC pipe, 50 mm rated diameter, insulator and flame non-propagator, impact resistance of 2 J, 1250 N compression resistance and 2000 V dielectric strength, with threaded union and surface mounted. (Ref: EG212B1H)	€/m	5,58
Tub rígid de PVC, de 63 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 2 J, resistència a compressió de 1250 N i una rigidesa dielèctrica de 2000 V, amb unió roscada i muntat superficialment. (Ref: EG212D1H) Rigid PVC pipe, 63 mm rated diameter, insulator and flame non-propagator, impact resistance of 2 J, 1250 N compression resistance and 2000 V dielectric strength, with threaded union and surface mounted. (Ref: EG212D1H)	€/m	6,71

Table 16: Tube and surface montage costs

In the Table 17 the costs of tube and underground mounting appear:

Item	Units	Cost
Tub rígid de PVC, de 50 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 3 J, resistència a compressió de 250 N, d' 1,2 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RB1G) Rigid PVC pipe, 50 mm rated diameter, insulator and flame non-propagator, impact resistance of 3 J, 250 N compression resistance, 1,2 mm thickness, with threaded union and underground mounted. (Ref: EG21RB1G)	€/m	3,18
Tub rígid de PVC, de 63 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 6 J, resistència a compressió de 250 N, d' 1,2 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RD1G) Rigid PVC pipe, 63 mm rated diameter, insulator and flame non-propagator, impact resistance of 6 J, 250 N compression resistance, 1,2 mm thickness, with threaded union and underground mounted. (Ref: EG21RD1G)	€/m	3,67
Tub rígid de PVC, de 75 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 6 J, resistència a compressió de 250 N, d' 1,2 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RF1G) Rigid PVC pipe, 75 mm rated diameter, insulator and flame non-propagator, impact resistance of 6 J, 250 N compression resistance, 1,2 mm thickness, with threaded union and underground mounted. (Ref: EG21RF1G)	€/m	4,25
Tub rígid de PVC, de 90 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 6 J, resistència a compressió de 250 N, d' 1,8 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RH1G) Rigid PVC pipe, 90 mm rated diameter, insulator and flame non-propagator, impact resistance of 6 J, 250 N compression resistance, 1,8 mm thickness, with threaded union and underground mounted. (Ref: EG21RH1G)	€/m	4,94
Tub rígid de PVC, de 110 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 12 J, resistència a compressió de 250 N, d' 1,8 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RK1G) Rigid PVC pipe, 110 mm rated diameter, insulator and flame non-propagator, impact resistance of 6 J, 250 N compression resistance, 1,8 mm thickness, with threaded union and underground mounted. (Ref: EG21RK1G)	€/m	6,05
Tub rígid de PVC, de 125 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 12 J, resistència a compressió de 250 N, de 2,2 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RL1G) Rigid PVC pipe, 125 mm rated diameter, insulator and flame non-propagator, impact resistance of 12 J, 250 N compression resistance, 2,2 mm thickness, with threaded union and underground mounted. (Ref: EG21RL1G)	€/m	7,08
Tub rígid de PVC, de 160 mm de diàmetre nominal, aïllant i no propagador de la flama, amb una resistència a l'impacte de 12 J, resistència a compressió de 250 N, de 2,2 mm de gruix, amb unió encolada i com a canalització soterrada. (Ref: EG21RN1G) Rigid PVC pipe, 160 mm rated diameter, insulator and flame non-propagator, impact resistance of 15 J, 250 N compression resistance, 2,2 mm thickness, with threaded union and underground mounted. (Ref: EG21RN1G)	€/m	9,42
Tub corrugat de PVC, de 50 mm de diàmetre nominal, aïllant y no propagador de la flama, resistència a l’impacte de 3 J, resistència a compressió de 250 N, muntat como canalització soterrada. (Ref: EG22RB1K)	€/m	1,66

PVC corrugated pipe, 50 mm rated diameter, insulator and flame non-flame propagator, impact resistance of 3 J, compressive strength of 250 N, mounted as a buried pipe. (Ref: EG22RB1K)		
Tub corrugat de PVC, de 65 mm de diàmetre nominal, aïllant y no propagador de la flama, resistència a l’impacte de 6 J, resistència a compressió de 250 N, muntat como canalització soterrada. (Ref: EG22RE1K) PVC corrugated pipe, 65 mm rated diameter, insulator and flame non-flame propagator, impact resistance of 6 J, compressive strength of 250 N, mounted as a buried pipe. (Ref: EG22RE1K)	€/m	1,93
Tub corrugat de PVC, de 80 mm de diàmetre nominal, aïllant y no propagador de la flama, resistència a l’impacte de 6 J, resistència a compressió de 250 N, muntat como canalització soterrada. (Ref: EG22RG1K) PVC corrugated pipe, 80 mm rated diameter, insulator and flame non-flame propagator, impact resistance of 6 J, compressive strength of 250 N, mounted as a buried pipe. (Ref: EG22RG1K)	€/m	2,52
Tub corrugat de PVC, de 100 mm de diàmetre nominal, aïllant y no propagador de la flama, resistència a l’impacte de 12 J, resistència a compressió de 250 N, muntat como canalització soterrada. (Ref: EG22RJ1K) PVC corrugated pipe, 100 mm rated diameter, insulator and flame non-flame propagator, impact resistance of 12 J, compressive strength of 250 N, mounted as a buried pipe. (Ref: EG22RJ1K)	€/m	3,14
Tub corrugat de PVC, de 125 mm de diàmetre nominal, aïllant y no propagador de la flama, resistència a l’impacte de 12 J, resistència a compressió de 250 N, muntat como canalització soterrada. (Ref: EG22RL1K) PVC corrugated pipe, 125 mm rated diameter, insulator and flame non-flame propagator, impact resistance of 12 J, compressive strength of 250 N, mounted as a buried pipe. (Ref: EG22RL1K)	€/m	4,09
Tub corrugat de PVC, de 160 mm de diàmetre nominal, aïllant y no propagador de la flama, resistència a l’impacte de 15 J, resistència a compressió de 250 N, muntat como canalització soterrada. (Ref: EG22RP1K) PVC corrugated pipe, 160 mm rated diameter, insulator and flame non-flame propagator, impact resistance of 15 J, compressive strength of 250 N, mounted as a buried pipe. (Ref: EG22RP1K)	€/m	5,44
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l’exterior, de 50 mm de diàmetre nominal, aïllant i no propagador de la flama, resistència a l’impacte de 15 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TB1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 50 mm rated diameter, insulator and non-flame spreader, impact resistance of 15 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TB1K)	€/m	1,85
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l’exterior, de 63 mm de diàmetre nominal, aïllant i no propagador de la flama, resistència a l’impacte de 20 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TD1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 63 mm rated diameter, insulator and non-flame spreader, impact resistance of 20 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TD1K)	€/m	2,16
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l’exterior, de 75 mm de	€/m	2,47

diàmetre nominal, aïllant i no propagador de la flama, resistència a l'impacte de 20 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TF1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 75 mm rated diameter, insulator and non-flame spreader, impact resistance of 20 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TF1K)		
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l'exterior, de 90 mm de diàmetre nominal, aïllant i no propagador de la flama, resistència a l'impacte de 20 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TH1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 90 mm rated diameter, insulator and non-flame spreader, impact resistance of 20 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TH1K)	€/m	2,86
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l'exterior, de 110 mm de diàmetre nominal, aïllant i no propagador de la flama, resistència a l'impacte de 28 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TK1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 110 mm rated diameter, insulator and non-flame spreader, impact resistance of 28 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TK1K)	€/m	3,29
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l'exterior, de 125 mm de diàmetre nominal, aïllant i no propagador de la flama, resistència a l'impacte de 28 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TL1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 125 mm rated diameter, insulator and non-flame spreader, impact resistance of 28 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TL1K)	€/m	3,93
Tub corrugat de polietilè, de doble capa, llisa la interior i corrugada l'exterior, de 160 mm de diàmetre nominal, aïllant i no propagador de la flama, resistència a l'impacte de 40 J, resistència a compressió de 450 N, muntat com canalització soterrada. (Ref: EG22TP1K) Polyethylene corrugated pipe, double layer, smooth inside and corrugated outside, 160 mm rated diameter, insulator and non-flame spreader, impact resistance of 40 J, compressive strength of 450 N, mounted as buried pipe. (Ref: EG22TP1K)	€/m	5,01

Table 17: Tube and underground mounting costs

In case of underground cable, the excavation costs must be included. These costs may fluctuate in a significant proportion in function of the dimension of the project. As an average value, the item of the Table 18 can be used to calculate the cost of excavation:

Item	Units	Cost
Excavació de rasa i pou de fins a 2 m de fondària, en terreny fluix (SPT < 20), realitzada amb retroexcavadora i amb les terres deixades a la vora. (Ref: E222142B) Excavation of a trench and a pit up to two meters deep in soft ground (SPT <20), realized with backhoe and soil left over. (Ref: E222142B)	€/m	4,50

Table 18: Costs of excavation for underground pipe

The high voltage cable installation costs per meter appear in Table 19. These cables are mounted without any pipe:

Item	**Units**	**Cost**
Línia elèctrica trifàsica de tensió mitjana (MT) de composició 3x1x95 mm^2, construïda per cables unipolars de designació UNE RHZ1 12/20 kV de 95 mm^2 de secció, amb conductor d'alumini, aïllament de polietilè reticulat (XLPE), pantalla metàl·lica de fils de coure de 16 mm^2 de secció i coberta exterior de poliolefina termoplàstica (Z1), soterrada. (Ref: EGK2L461) Medium voltage three-phase line, 3x1x95 mm^2 design, made of one-phase 95 mm^2 section cables with UNE RHZ1 12/20 kV designation, aluminium wire, XLPE isolation, 16 mm^2 section copper metallic shield and thermoplastic polyolefin exterior cover, underground mounted. (Ref: EGK2L461)	€/m	26,87
Línia elèctrica trifàsica de tensió mitjana (MT) de composició 3x1x95 mm2, construïda per cables unipolars de designació UNE RHZ1 18/30 kV de 95 mm2 de secció, amb conductor d'alumini, aïllament de polietilè reticulat (XLPE), pantalla metàl·lica de fils de coure de 16 mm2 de secció i coberta exterior de poliolefina termoplàstica (Z1), soterrada. (Ref: EGK2L661) Medium voltage three-phase line, 3x1x95 mm2 design, made of one-phase 95 mm2 section cables with UNE RHZ1 18/30 kV designation, aluminium wire, XLPE isolation, 16 mm2 section copper metallic shield and thermoplastic polyolefin exterior cover, underground mounted. (Ref: EGK2L661)	€/m	30,39
Línia elèctrica trifàsica de tensió mitjana (MT) de composició 3x1x95 mm2, construïda per cables unipolars de designació UNE HEPRZ1 12/20 kV (DHZ1 12/20 kV) de 95 mm2 de secció, amb conductor d'alumini, aïllament d'etilè-propilè (EPR), pantalla metàl·lica de fils de coure de 16 mm2 de secció i coberta exterior de poliolefina termoplàstica (Z1), soterrada. (Ref: EGK2N461) Medium voltage three-phase line, 3x1x95 mm2 design, made of one-phase 95 mm2 section cables with UNE HEPRZ1 12/20 kV designation (DHZ1 12/20 kV), aluminium wire, EPR isolation, 16 mm2 section copper metallic shield and thermoplastic polyolefin exterior cover, underground mounted. (Ref: EGK2N461)	€/m	27,75
Línia elèctrica trifàsica de tensió mitjana (MT) de composició 3x1x95 mm2, construïda per cables unipolars de designació UNE HEPRZ1 18/30 kV (DHZ1 18/30 kV) de 95 mm2 de secció, amb conductor d'alumini, aïllament d'etilè-propilè (EPR), pantalla metàl·lica de fils de coure de 16 mm2 de secció i coberta exterior de poliolefina termoplàstica (Z1), soterrada. (Ref: EGK2N661) Medium voltage three-phase line, 3x1x95 mm2 design, made of one-phase 95 mm2 section cables with UNE HEPRZ1 18/30 kV designation (DHZ1 18/30 kV), aluminium wire, EPR isolation, 16 mm2 section copper metallic shield and thermoplastic polyolefin exterior cover, underground mounted. (Ref: EGK2N661)	€/m	31,73

Table 19. High voltage cable and installation costs

General Electrical Protection Box (CGP)

Assuming the range of power supplied, there are different types of GPBs that may be installed. The costs of the equipment and montage appear together in Table 20:

Item	Units	Cost
Caixa general de protecció de polièster reforçat amb fibra de vidre, de 100 A, segons esquema UNESA número 7, seccionable en càrrega (BUC), inclosa base portafusibles trifàsica (sense fusibles), neutre seccionable, borns de connexió i grau de protecció IP-43, IK09, muntada superficialment. (Ref: EG116762) General electrical protection box of reinforced polyester with fiberglass, 100 A, according to scheme UNESA number 7, isolatable load (BUC), including fuse-phase (without fuse), neutral isolatable, terminals and degree of protection IP-43, IK09, surface mounted. (Ref: EG116762)	€/u	185,55
Caixa general de protecció de polièster reforçat amb fibra de vidre, de 160 A, segons esquema UNESA número 7, seccionable en càrrega (BUC), inclosa base portafusibles trifàsica (sense fusibles), neutre seccionable, borns de connexió i grau de protecció IP-43, IK09, muntada superficialment. (Ref: EG116A62) General electrical protection box of reinforced polyester with fiberglass, 160 A, according to scheme UNESA number 7, isolatable load (BUC), including fuse-phase (without fuse), neutral isolatable, terminals and degree of protection IP-43, IK09, surface mounted. (Ref: EG116A62)	€/u	191,29
Caixa general de protecció de polièster reforçat amb fibra de vidre, de 160 A, segons esquema UNESA número 9, seccionable en càrrega (BUC), inclosa base portafusibles trifàsica (sense fusibles), neutre seccionable, borns de connexió i grau de protecció IP-43, IK09, muntada superficialment. (Ref: EG11CA62) General electrical protection box of reinforced polyester with fiberglass, 160 A, according scheme UNESA No. 9, isolatable load (BUC), including fuse-phase (without fuse) isolatable neutral, terminals and degree of protection IP- 43, IK09, surface mounted. (Ref: EG11CA62)	€/u	165,88
Fusible NH-1 100 A (Ref: www.electromaterial.com) 100 A NH-1 Fuse (Ref: www.electromaterial.com)	€/u	5,90
Fusible NH-1 160 A (Ref: www.electromaterial.com) 160 A NH-1 Fuse (Ref: www.electromaterial.com)	€/u	5,90

Table 20. Costs of General Protection Box and its installation

This equipment use to remain into a second protection box, which guarantees a better level of protection. It is called the double insulation box. The prices of a typical double protection box and the installation costs appear together in Table 21:

Item	Units	Cost
Caixa de doble aïllament de polièster reforçat de 360 x 360 x 170 mm i muntada superficialment. (Ref: EG121D02) Double insulation box of reinforced polyester of 360 x 360 x 170 mm, surface mounted. (Ref: EG121D02)	€/u	65,80
Caixa de doble aïllament de ABS, de 360 x 540 x 210 mm i muntada superficialment. (Ref: EG123G02) ABS double insulation box, 360 x 540 x 210 mm, surface mounted. (Ref: EG123G02)	€/u	82,88

Table 21. Cost of doubly isolated boxes and montage

5. Infrastructure evolution scenarios

This final chapter foresees the future scenarios in infrastructure terms, defining the main factors of growth of the infrastructure, describing how the infrastructure could grow and defining the different sets in terms of infrastructure type growth and finally explaining the cost analysis to be able to measure the expansion of the network.

Scenarios

Different possible scenarios are proposed to understand how the infrastructure proposed to charge EV from railway stations can be used in the present, considering the actual network of charging points and in the future, when this network is enlarged.

The first scenario to consider is the existing EV charging station network (Scenario 1). Then, it evolves to a scenario (Scenario 2) which considers off-street chargers (not located specifically in streets). Finally, the second scenario is widen, so enlarging new installations with both on street and off street chargers (Scenario 3).

Assumptions

For the analysis of the before mentioned scenarios, the following aspects are assumed:

- The new infrastructure belongs to a distribution company
- For off-street installations the power installed for EV charging can be (as described in Section 4.3):
    a) AC single-phase (230 V) with usual power rating between 3,6 and 7,2 kW
    b) AC three-phase (400 V) with usual power rating between 11 and 22 kW

  While for on-street installations, EV charging stations can be:
    a) AC single-phase (230 V) with usual power rating between 7,2 kW
    b) AC three-phase (400 V) with usual power rating between 11 and 22 kW
    c) Direct current (DC) with usual power rating between 20 and 50 kW
- At the end installation there is not enough space for a transformer, so its installation will be at the origin of the electrical infrastructure (in the railway station). Under these circumstances, the cabling used to transmit the electrical energy from the railway station to the EV charging points is LV.
- The available power at the railway station is sufficient.

Based on these assumptions, calculations are performed (and shown in Table 24) to show the cabling characteristics needed for feeding the EV charging stations according to the topology depicted in Figure 7 (Option 3), which specifies the *origin* and *end* of the new installation that could be the most feasible one according to the rated current.

Although the route of the installation is identified in Figure 7, some assumptions are required so as to find the cable sizing and length that could be used. Calculations are performed assuming the LV cable is installed in ventilated gallery, with an air temperature of 40ºC. The cable is tetrapolar (3-phase+neutral), with copper (Cu) conductors (ρ_{Cu}=0.021 Ωmm^2/m), with XLPE insulation.

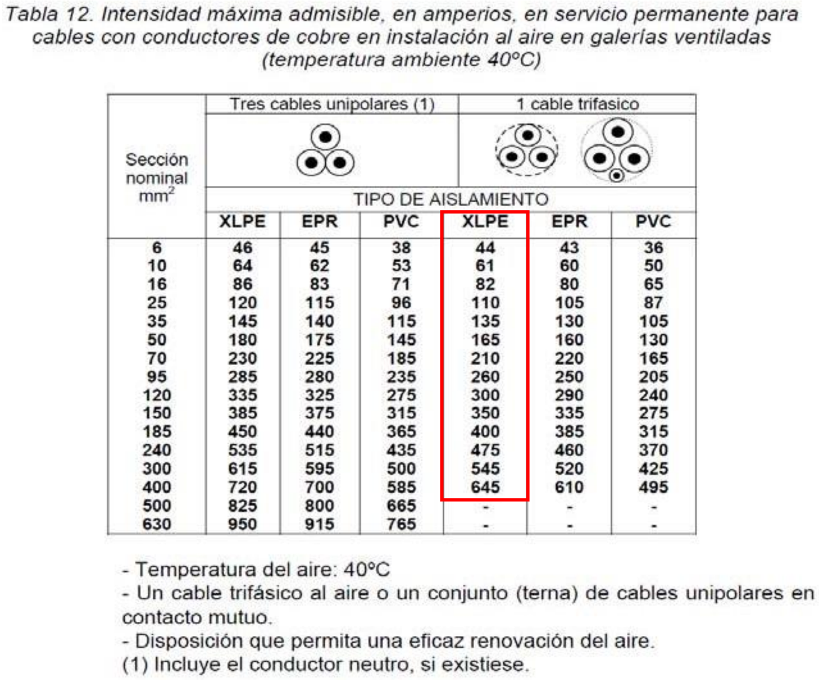


Tabla 12. Intensidad máxima admisible, en amperios, en servicio permanente para cables con conductores de cobre en instalación al aire en galerías ventiladas (temperatura ambiente 40ºC)

Sección nominal mm²	Tres cables unipolares (1)			1 cable trifasico		
	TIPO DE AISLAMIENTO					
	XLPE	EPR	PVC	XLPE	EPR	PVC
6	46	45	38	44	43	36
10	64	62	53	61	60	50
16	86	83	71	82	80	65
25	120	115	96	110	105	87
35	145	140	115	135	130	105
50	180	175	145	165	160	130
70	230	225	185	210	220	165
95	285	280	235	260	250	205
120	335	325	275	300	290	240
150	385	375	315	350	335	275
185	450	440	365	400	385	315
240	535	515	435	475	460	370
300	615	595	500	545	520	425
400	720	700	585	645	610	495
500	825	800	665	-	-	-
630	950	915	765	-	-	-

- Temperatura del aire: 40ºC
- Un cable trifásico al aire o un conjunto (terna) de cables unipolares en contacto mutuo.
- Disposición que permita una eficaz renovación del aire.

(1) Incluye el conductor neutro, si existiese.

Table 22 Maximum allowed current for copper cables in ventilated installations in galleries. Source: ITC-BT-07

Calculations

With the previously detailed specifications for the cable, the tabulated values extracted from the ITC-BT-07 (Table 22) is used to perform the calculations depicted in Table 24. These allow to determine the normalized section corresponding to a maximum admitted current. As explained in Section 4.3, the cable selection needs to accomplish the criteria of maximum admitted current and also a maximum voltage drop. So, at the end, the section chosen is the most restrictive one.

All these calculations have been performed assuming the cable required is LV and will be very similar in case it was HV. However the tables to be consulted are in ITC-LAT-06 and the voltage drops might differ.

As the length of the cable is not known (it will depend on the *origin* and *end* installation locations), different lengths are considered (50 m, 100 m, 150 m and 300 m) and the cable section that corresponds to the maximum section between the corresponding to the maximum admitted current and the maximum voltage drop is determined for each length. Furthermore, the maximum length that each installation allows is also calculated. It basically depends on the power required at the *end* of the installation, rated voltage, power factor and voltage drop.

The results depicted in Table 24 are used to explain how the electrical infrastructure of railway stations could feed specific EV charging points in Barcelona city for the different scenarios defined. Off-street chargers are compatible with Installations 1, 2, 3, 4 and 5, whilst on-street chargers are compatible with all of them: 1, 2, 3, 4, 5, 6, 7 and 8.

The existing B:SM parking of Boqueria is taken as a sample case. It is an underground parking and the requirements from its new charging infrastructure from underground electric system according to the scenarios quoted previously will be described next:

- **Scenario 1.** Actually the public parking in *Boqueria*, can feed 9 EVs with single-phase chargers. Assuming that each EV charging point is single-phase with 2.3 kW, the power to be installed must be, at least, 20.8 kW. According to the Table 24 different installation options are possible to provide this power. For instance, Installation 6 (35 kW), 7 (44 kW) would provide more power than the needed for 9 charging stations. Installation 8 (50 kW) should be discarded because fast charging is not thought for off-street. Installations 3 (22,2 kW) and 5 (22 kW) are possible. The new transformer required, is oversized enough considering future expansion of the EV charging facility.
- **Scenario 2.** The existing EV charging station is enlarged with off-street chargers. We can imagine, using the previous example, that in Boqueria charging station, 3 new points for EV charging are installed (6,9 additional kW are required). Therefore, in this case we can feed 12 EVs and the idea is to use the existing infrastructure for feeding the already existing 9 EV points. Supposing that the chosen installation in scenario 1 was installation 5, the already available power is 22-20.8 = 1.2 kW. Hence, as there is not enough available power, new cables are required. So, the 3 new EV charging points will be fed by Installation 1 (6,9 kW), Installation 2 (11.1 kW), Installation 3 (22.2 kW) or Installation 4 (11 kW). As the transformer mentioned in Scenario 1, was oversized (knowing the future expansion plan of EV charging points), there is no need to install another one.
- **Scenario 3.** The EV charging station is enlarged with on-street and off-street chargers, so we could assume we have Scenario 2 and the parking area is extended so that EV points can be either off street or on street. In scenario 2, all EV points were off-street (so, fast chargers were no installed). We assume 1 new EV charging point is installed on-street (35 additional kW are required). In this case, Installation 6 (35 kW), Installation 7 (44 kW) and Installation 8 (50 kW) supply more power than the needed power of these EV points. Hence, installing additional cables according to any of these installations are valid options.

Cost estimation

In order to know how much could cost the installation that would allow to feed EV charging points from the railway station to the parking where they are located, a case study based on Scenario 1.

The new power transformer (transformation centre) can be installed in the metro facilities at the same room than the other transformation centres. So, no additional civil works will be needed for its installation.

The power rating of this new transformer must take into account the number of EV charging points to be feed at the moment it is installed as well as the EV charging points that will be placed in the future. In Scenario 1, 9 EV charging points (single-phase 2.3 kW) are located in the parking. We know that in the future, 3 new EV charging points will be installed off-street and 1 on-street. Hence, the power rating required is, at least, 9*2.3+3*2.3+1*35 = 62.6 kW.

The distance between Metro installation and EV charging facility is 100 m. According to Table 24 and Installation 5, the cable section will be 25 mm^2. It is supposed that the cable installation will be in gallery (50 m) and undergrounded (50 m).

According to previous assumptions, there is no need for a transformation building. So, the transformer cost including its installation can be estimated using Table 11: 6000 €. The protection system (3 fuses) must be installed in a protection box. The protection box plus its installation accounts for 200 € approximately (Table 20) and the fuses cost will be 3*5=15 € (Table 20).

The 25 mm^2 tetrapolar cable (three-phases+neutral) cable costs 8.3 €/m. So, the 100 m required will cost 830 € (Table 15). According to Table 16, the surface mounting (50 m) will cost around 192 € and the underground mounting (50 m) cost can be approximated to 159 € (Table 17). To mount the 50 m underground cable, it is required the corresponding excavation.

The total cost estimated for this new electrical infrastructure is shown in Table 23. Civil works required for installing the cable are not considered.

Equipment	Estimated cost*
Power transformer	6000 €
Cabling	830 €
LV protections+General protection box	215 €
Total cable installation	351 €
TOTAL cost*	**7396 €**

*Civil works are not included

Table 23. Estimated cost of the interconnection between railway and EV charging facility

Installation	Active power demand (P_d) [kW]	Power Factor	Rated Voltage (U_0) [V]	Required current [A]	Maximum voltage drop [%]	Maximum voltage drop [V]	1. Minimum section: current criterion (ITC-BT-07) [mm^2]	2. Minimum section: voltage drop criterion [mm^2]				Minimum section: max{1,2}				Selected standard cable section [mm^2]				Maximum permitted length (maximum normalized cable section = 400 [mm^2]) [m]
								L=50 [m]	L=100 [m]	L=150 [m]	L=300 [m]	L=50 [m]	L=100 [m]	L=150 [m]	L=300 [m]	L=50 [m]	L=100 [m]	L=150 [m]	L=300 [m]	
1	6,9	1,0	230,0	10,0	1,5	6,0	6,0	3,0	6,1	9,1	18,2	6,0	6,1	9,1	18,2	6	10	10	25	6598
2	11,1	1,0	230,0	16,1	1,5	6,0	6,0	4,9	9,8	14,6	29,3	6,0	9,8	14,6	29,3	6	10	16	35	4102
3	22,2	1,0	230,0	32,2	1,5	6,0	6,0	9,8	19,5	29,3	58,5	9,8	19,5	29,3	58,5	10	25	35	70	2051
4	11,0	1,0	400,0	15,9	1,5	6,0	6,0	4,8	9,6	14,4	28,9	6,0	9,6	14,4	28,9	6	10	16	35	4156
5	22,0	1,0	400,0	31,8	1,5	6,0	6,0	9,6	19,3	28,9	57,8	9,6	19,3	28,9	57,8	10	25	35	70	2078
6	35,0	1,0	400,0	50,5	1,5	6,0	10,0	15,3	30,6	45,9	91,9	15,3	30,6	45,9	91,9	16	35	50	95	1306
7	44,0	1,0	400,0	63,5	1,5	6,0	16,0	19,3	38,5	57,8	115,5	19,3	38,5	57,8	115,5	25	50	70	120	1039
8	50,0	1,0	400,0	72,2	1,5	6,0	16,0	21,9	43,8	65,6	131,3	21,9	43,8	65,6	131,3	25	50	70	120	914

* Installations 1,2 and 3 can be used for single-phase charging points, but the cabling has been sized for a three-phase+neutral distribution line..

Table 24 Cable sizing for different active power demands at the EV charging station

References

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[8] https://itec.cat

[9] Reglamento sobre condiciones técnicas y garantías de seguridad en instalaciones eléctricas de alta tensión (2014)

Real Decreto 223/2008, de 15 de febrero, por el que se aprueban el Reglamento sobre condiciones técnicas y garantías de seguridad en líneas eléctricas de alta tensión y sus instrucciones técnicas complementarias ITC-LAT 01 a 09. (BOE 19.03.08)

[10] Real Decreto 842/2002, de 2 de agosto, por el que se aprueba el Reglamento electrotécnico para baja tensión (BOE 18.09.02).

[11] Real Decreto 1053/2014, de 12 de diciembre, por el que se aprueba una nueva Instrucción Técnica Complementaria (ITC) BT 52 "Instalaciones con fines especiales. Infraestructura para la recarga de vehículos eléctricos", del Reglamento electrotécnico para baja tensión, aprobado por Real Decreto 842/2002, de 2 de agosto, y se modifican otras instrucciones técnicas complementarias del mismo. (BOE 31.12.14)

[12] Ley 24/2013, de 26 de diciembre, del Sector Eléctrico. BOE núm. 310, de 27/12/2013.

Annex

Next figure shows the current parking lots at B:SM facilities with charging points for electric vehicles.

P00 Recàrrega motos i cotxes elèctrics
Recarga motos y coches eléctricos
It recharges motorcycles and electrical cars
Il recharge des motos et des voitures électriques

P00 Recàrrega cotxes elèctrics
Recarga coches eléctricos
It recharges electrical cars
Il recharge des voitures électriques

P00 Recàrrega motos elèctriques
Recarga motos eléctricas
It recharges electrical motorcycles
Il recharge des motos électriques

Més de 40 aparcaments al vostre servei:

01 **Almogàvers-Llacuna**
C/ de la Llacuna, 101

02 **Avinguda Gaudí**
C/ de Cartagena, 319

03 **Badajoz**
C/ Badajoz, 168

04 **Bilbao-Llull**
C/ de Bilbao, 24

05 **Bus Garcia Fària**
Pg. de Garcia Fària, 71

06 **Bus Moll d'Espanya**
Pg. de Garcia Fària, 71

07 **Cardenal Sentmenat - Vergós**
Cardenal Sentmenat, 8

08 **Ciutat del Teatre**
C/ de la França Xica, 35

09 **Concepción Arenal**
C/ de Concepción Arenal, 143

10 **Cotxeres de Sarrià**
Pg. de Manuel Girona, 77

11 **Estació Barcelona Nord**
C/ d'Alí Bei, 54

12 **Ferran Casablancas**
C/ de Josep Balari, 17

13 **Flos i Calcat**
C/ de Flos i Calcat, 2

14 **Gràcia Motos**
C/ Gran de Gràcia, 190-192

15 **Hospital del Mar**
Pg. Marítim Barceloneta, 23-31

16 **Illa Borbó**
Ramon Albó, 77 s

17 **Boqueria, La**
Floristes de la Rambla, s/n

18 **Litoral Port**
Av. del Litoral, 34

19 **Marina Gràcia**
C/ de la Marina, 345

20 **Marina Port**
C/ de la Marina, 13-17

21 **Marquès de Mulhacén**
C/ Marquès de Mulhacén, 51

22 **Mercat Guinardó**
C/ Teodor Llorente, 10

23 **Mercat Sagrada Família**
C/ de Mallorca, 425 - 433

24 **Mitre - Putxet**
Rda. General Mitre, 203

25 **Moll de la Fusta**
Pg. de Colom, 1

26 **Ona Glòries**
C/ de la Ciutat de Granada, 173

27 **P.R. Biomèdica**
C/ del Dr. Aiguader, 88

28 **Passeig Maragall**
Pg. Maragall, 54

29 **Plaça Bonanova**
Pl. de la Bonanova, 2

30 **Plaça de les Arts**
C/ de Padilla, 159

31 **Plaça del Fòrum**
Pl. d'Ernest Lluch i Martín, s/n

32 **Plaça Francesc Layret**
Via Júlia, 95

33 **Plaça Joanic**
C/ de l'Escorial, 1

34 **Plaça Navas**
C/ Jaume Fabra, 10

35 **Porta de Sarrià**
C/ de Salvador Mundi, 17

36 **Rambla Poblenou**
Rbla. del Poblenou,130

37 **Rius i Taulet**
Av. Reina Maria Cristina, 16

38 **Sant Andreu Teatre**
C/ de les Monges, 2

39 **Sant Genís-Vall d'Hebron**
Pg. de la Vall d'Hebron, 138-176

40 **Tanatori Les Corts**
Av. Joan XXIII, 25

41 **Torrent de l'Olla**
C/ del Torrent de l'Olla, 221

42 **Wellington-Zoo**
C/ Ramon Trias Fargas, 19

Aparcament amb servei recàrrega de cotxes i motos elèctriques

Aparcament amb servei recàrrega de cotxes elèctrics

Aparcament amb servei recàrrega de motos elèctriques

AP10VH0416