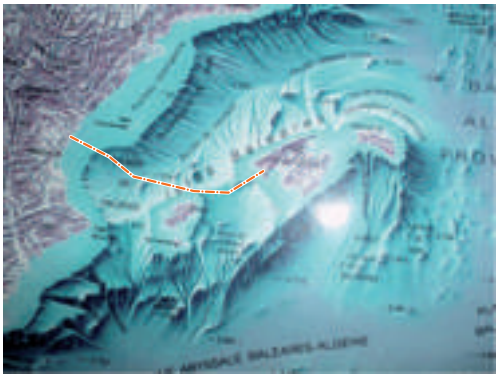
RED ELÉCTRICA
DE ESPAÑA

RÓMULO

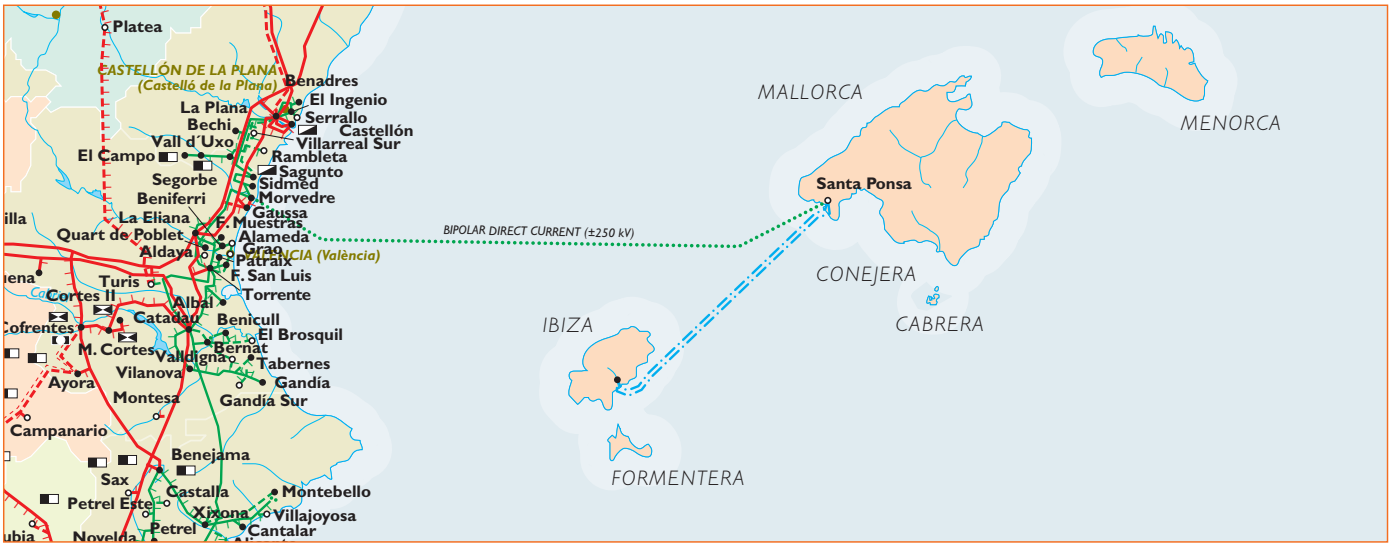
PENINSULA-BALEARIC ISLANDS ELECTRICITY INTERCONNECTION



The electricity interconnection between the Iberian Peninsula and the Balearic Islands is fundamental to ensure and improve reliability of the electricity supply and to promote competitiveness in electricity generation.

Red Eléctrica de España is the company responsible for carrying out this submarine electricity interconnection project which was completed in 2011 with the commissioning of this interconnection line along with the converter stations of Morvedre (400 kV) in Sagunto (Valencia), and Santa Ponsa (220 kV) in Calviá (Majorca). This is the first submarine high-voltage direct current (HVDC) transmission link in Spain, and it ranks second in the world in terms of maximum depth at which the cables are laid (1,485 metres). This depth is currently only exceeded by the link between Sardinia and mainland Italy, where the maximum depth is 1,600 metres.

Amongst the advantages of this interconnection with the Spanish peninsula noteworthy is the increase in both the quality and reliability of the electricity supply in the Balearic Islands' system. Furthermore, the integration with the peninsular system allows the connection to the "Iberian electricity market", something that was previously impossible due to the unique nature of the insular electricity systems, which do not allow a competitive generation market to be established on the Islands.



The electricity interconnection is a complementary option to the construction of generation stations on the Islands, and unlike other alternatives has a far more favourable impact on the environment of the Balearic Islands'. From an economic standpoint, the commissioning of this infrastructure represents a cost savings for the national electricity system.

All the required infrastructure for this electricity interconnection is set forth in the 2008-2016 Electricity and gas sectors planning. Development of transmission grids. (*Planificación de los sectores de electricidad y gas 2008-2016. Desarrollo de las redes de transporte*), approved in May 2008, which incorporated the interconnection between the Peninsular electricity system and that of the Balearic Islands. These planning reports are aimed at meeting the forecasted demand and minimum developmental requirements for electricity interconnections and infrastructure, with the aim to guarantee the demand, in line with adequate security and quality standards, for the next decade.

In the Balearic Islands the evolution of the demand is influenced by the development of the services sector which has significant potential for future development. In this respect, the Balearic Islands' electricity system must be prepared for all possible scenarios and also needs to evolve towards an efficient and sustainable model that guarantees cost savings for the entire electricity system, ensures the quality and security of supply, and additionally reduces CO_2 emissions.

Platform for storing submarine cable in one continuous length.

Actual demand in the Balearic Islands´ electricity system (2004-2011)

Year	Total (MWh)	Hourly max. (MWh)	Annual increase (%)
2004	5,437,317	1,085	4.73
2005	5,709,845	1,095	5.01
2006	5,828,529	1,201	2.08
2007	5,963,142	1,145	2.30
2008	6,091,947	1,225	2.17
2009	6,028,152	1,207	-1.50
2010	5,887,000	1,157	-1.70
2011	5,716,000	1,164	-2.90

Submarine power transmission cable on the deck of the *Giulio Verne*.

Vessels used to lay submarine power cables.

Interior of the Santa Ponsa converter station.

Rómulo Project

The Balearic Islands' electricity system was made up of two independent sub-systems: Majorca-Menorca and Ibiza-Formentera, not connected to the electricity system on the Spanish peninsula. In order to meet the ever-increasing demand on the Islands and enhance the quality and reliability of supply, towards the end of 2004 Red Eléctrica began analysing and defining the new interconnection, via detailed technological, electrical, environmental and economic studies. The chosen technical solution consists of unifying the Balearic Islands' electricity system by linking the two existing sub-systems, and then linking the Balearic Islands' electricity system to the one on the Spanish peninsula.

The Rómulo Project "The Spanish Peninsula-Balearic Islands Electricity Interconnection" represents the largest investment ever made by Red Eléctrica in any one single project.

In May 2007, Red Eléctrica awarded the contracts for construction of the submarine electricity interconnection between the Spanish peninsula and the Balearic Islands to the German company Siemens, which will be in charge of constructing the converter station at Sagunto (Valencia) and Calviá (Majorca), and to the consortium comprising of the Italian company Prysmian and the Norwegian company Nexans, which will be in charge of designing, manufacturing and laying the submarine power cables. Red Eléctrica managed to harness the production capacity of two of the companies with the most expertise in this highly specialised field, thus reducing the project's overall execution time.

The total amount awarded in these two contracts was 375 million euros and, due to the specialised nature of the work involved, it has been divided into two major areas.

The unification of the Balearic Islands' electricity system and its link to the Spanish peninsular electricity system, paves the way for optimising the introduction of new generation on the Islands. It will also provide a more reliable and secure supply to the entire Balearic Islands' system.

Red Eléctrica de España was the Spanish company responsible for the Remo project (*Refuerzo Eléctrico Mediterráneo Occidental* -Western Mediterranean Electricity Reinforcement)- the electricity interconnection between Spain and Morocco commissioned in 2006. Now, in a tribute to the two historical figures, the company responsible for carrying out the submarine electricity interconnection between the Spanish peninsula and the Balearic Islands decided to name this second link the Rómulo project.

Spanish peninsula-Majorca link

The Morvedre substation (400 kV) was chosen as the link-up point with the mainland, based on several criteria: the shortest distance, the relatively shallow depth of the sea and other characteristics of the undersea route. On the Majorcan side, the link-up point is with the Santa Ponsa substation (220 kV).

It is a high-voltage submarine electricity connection, at ±250 kV, using a 400 MW bipolar connection which uses High Voltage Direct Current (HVDC) technology, given the distances covered and capacities required. The submarine cables are 237 km long, and run at a maximum depth of 1,485 metres.

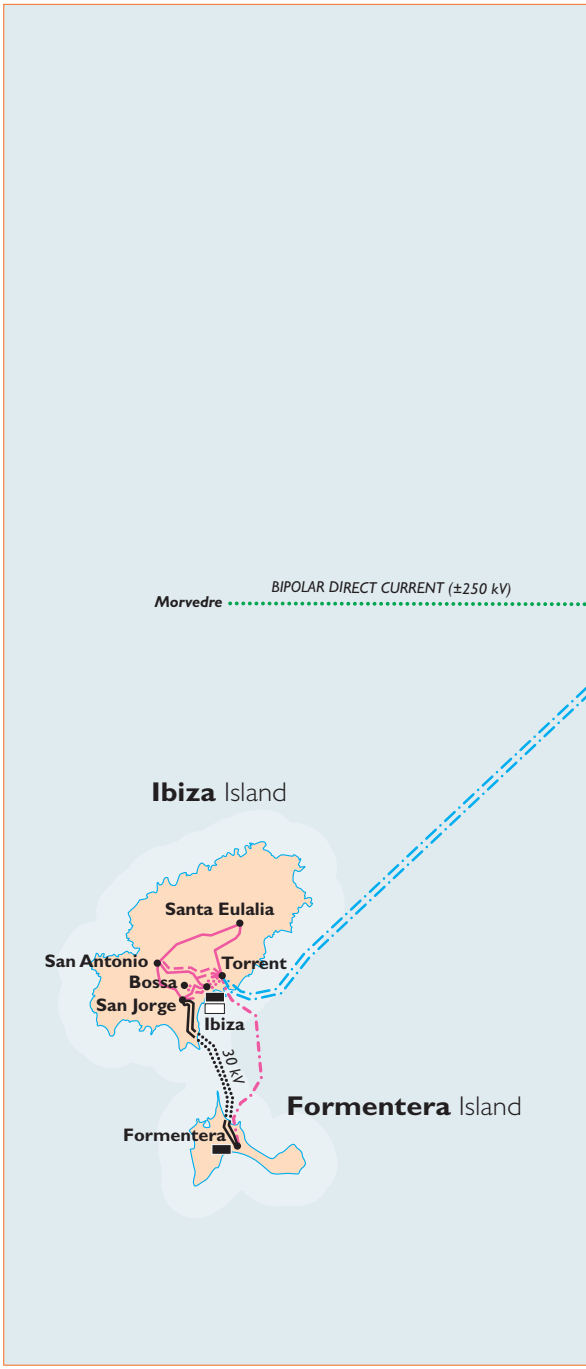
The bipolar or dual links are considered to be essential to attain adequate levels of reliability and security of supply and to enable it to function correctly, in the event of any of its elements being reviewed or maintained. Since it is the only link to the Spanish peninsula, one of the most important factors to be taken into account is a high level of availability.

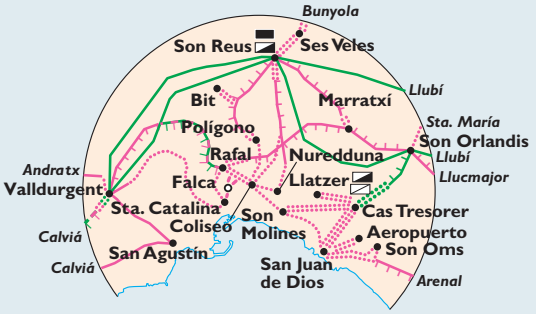
The project also includes the construction of two converter stations, one at either end, ensuring the operation of the interconnection in order to link the two electricity systems. The unique nature of this project makes it necessary to construct converter stations to transform the alternating current running through the transmission grid into direct current, so that current flows through the submarine cable under optimum conditions with the aim to reduce transmission power losses resulting from the considerable length of the cable. Furthermore, land sections of underground cables just over 3 km in length were built at each end, to connect to the converter stations.

Environmental actions

In designing this project, Red Eléctrica has implemented a comprehensive set of preventive and corrective measures aimed at minimising any effect on the natural and social environment in which the new facilities are located.

Prior to choosing the final route, a number of alternatives were assessed, between various grid hubs on the peninsula's Mediterranean coast and the Balearic Islands' grid. For each alternative, account was taken of the constraints deriving from the environmental conditions of the territory, including protected areas, in order to identify and classify the possible interconnection solutions.





Situation January 1, 2012

Lines	Circuits planned	Circuits installed
In service	1	1
	2	1
	2	2
Under construction and planned	1	1
Underground/submarine line: In service		
Underground/submarine line: Under construction and planned		
Lines planned for transformation to higher voltage		

Voltages
220 kV
132 kV
66 kV
< 66 kV

	In service	Under construction and planned
Substations	•	○
Power plants: Hydro	⋈	⋈
Power plants: Fossil-fuel	■	□
Power plants: Combined cycle	◪	◪
Power plants: Wind farm	◧	◧

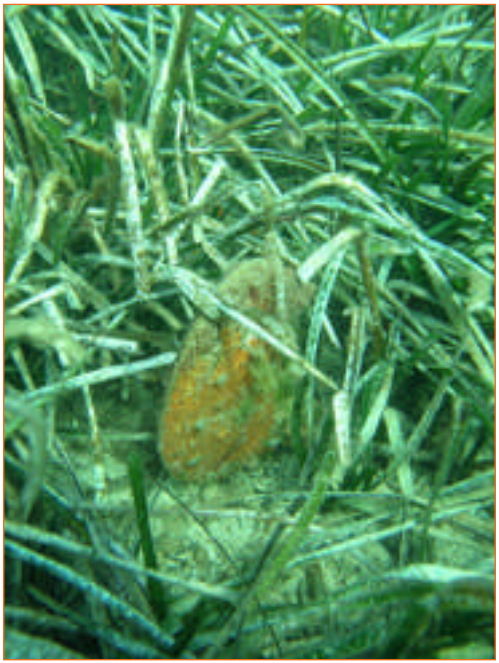
Firstly, the substations of La Eliana, Benejama and La Plana were ruled out, due to the major environmental impact of the land sections. In a second phase, other possible solutions in Sagunto, Torreblanca and Vandellós were considered. The latter two were ruled out because of the existence of areas protected by "Natura 2000", and the presence of sections of the seabed which were deemed unstable.

Finally, it was decided that the most feasible solution and of least environmental impact, was the interconnection between the Morvedre and Santa Ponsa substations.

The proposed route for the submarine cables was designed based on a detailed study of the seabed, measuring the bathymetry and physical characteristics of the subsoil along a 2 km-wide corridor covering the entire route.

In its underground and coastal sections, the chosen route avoids archaeological remains, fish farms and seagrass meadows in the Sagunto area. The preventive environmental measures minimise the effect on the tourist and fishing sectors, on cetaceans and on the Mediterranean fan mussel (which inhabits Posidonia Oceanica seagrass meadows) in the undersea section, and Greek tortoises in the land section of Santa Ponsa.

One of the most environmentally valuable items analysed is the Posidonia Oceanica seagrass meadows, a Mediterranean species which is protected at European level. By implementing preventive, corrective and offsetting measures, the impact on this seagrass, which grows in the Santa Ponsa cove, has been minimised.



Posidonia seagrass meadow, protected habitat, with presence of fan mussels.

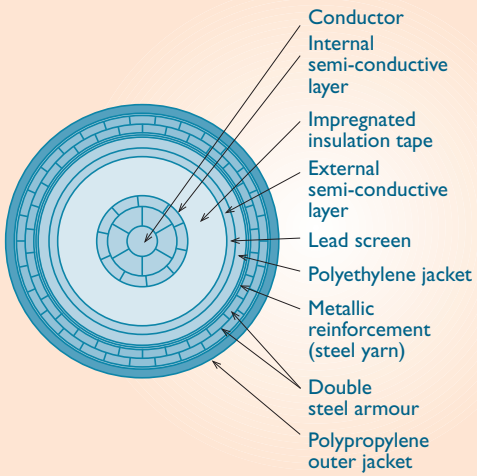
Manufacturing and method of laying submarine cables

The companies in charge of designing and laying the cables, the Norwegian company Nexans and the Italian company Prysmian, each manufactured one of the submarine HVDC cables (237 km) and half of the return submarine cable (118.5 km), making a total of 711 km of cable. Once the cables are manufactured and factory-tested, they are moved to large rotating platforms at the companies' facilities and are subsequently loaded directly onto the only two vessels in the world capable of undertaking this kind of cable-laying project, the *Skagerrak* and the *Giulio Verne*.

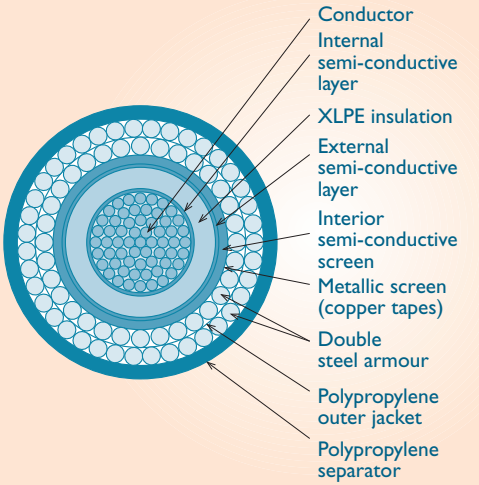
These vessels are equipped with dynamic global positioning systems (DGPS) to accurately follow the planned routes and to remain steady when sea

Thorough search of the Santa Ponsa Bay by means of imaging sonar to detect the position of posidonia meadows.

Submarine HVDC cable



Return submarine cable



conditions require the work to be suspended for a few hours. The vessels are able to control and adjust their positions to a high degree of precision, using DGPS which sets their coordinates at any given time and automatically controls their position using 5 adjustable propulsion units.

The ship is positioned 500 metres from the coast, and from there it travels along the entire pre-established route, laying the cable on the seabed. When it reaches the opposite coast, it stops, and releases the remaining cable which, using floatation devices, auxiliary vessels and divers, is placed along the seabed up to the shore. The submarine cables are protected beneath the seabed inside a 1 metre-deep trench at depths of less than 800 metres.

Each ship has the capacity to transport 7,000 tonnes of cable, which is vital for laying each of these power lines, whose total weight is an estimated 6,700 tonnes. Accordingly, each submarine cable is laid in one continuous length, and it is therefore there is no need for splicing during the laying works.

The *Giulio Verne*, a cable-laying vessel, which belongs to Prysmian and the *Skagerrak*, which belongs to Nexans, each lay one of the HVDC cables. Once the direct current submarine cables have been laid, the fibre-optic cables necessary to guarantee communications between both ends of the link are laid.

The process of laying the cables is closely monitored so as to ensure that the cable is correctly placed on the seabed, using a remote control vehicle (RCV) for small adjustments in the route and to negotiate irregularities in the seabed.

General project planning

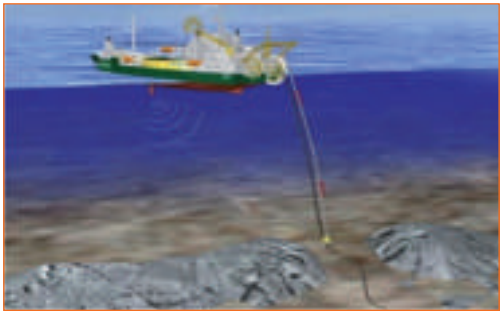
Project history

- **July 2005-March 2006**
  Summary report to the Environment Ministry.
- **July 2005-October 2007**
  Drafting of Environmental Impact Assessment and execution plans.
- **February 2008-July 2009**
  Administrative processing of environmental impact assessment and execution plans.

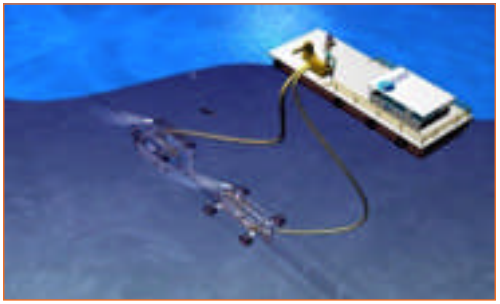
Simulation of the process of burying cables under the seabed.

Engineering and construction of the interconnection

- **November 2004-April 2006**
  Feasibility studies.
- **April 2005- April 2006**
  Study of the seabed along the route.
- **May 2007**
  Contracts awarded.
- **June 2007-May 2008**
  Detailed engineering plans.
- **2008-2010**
  Manufacturing of cables and equipment.
- **April 2009-December 2010**
  Construction of converter stations.
- **2010-2011**
  Laying of cables and assembly.
- **2011-2012**
  Testing and putting in service.
- **August 2012**
  Start of the Commercial Operation.



Remote control vehicle for correctly positioning the cable on the seabed.



Equipment for digging cable trench in shallow areas.

The *Skagerrak*, Norwegian vessel belonging to Nexans designed specially for undersea cable-laying.

General characteristics of the Spanish peninsula-Majorca project

System	Direct current system
Nominal voltage	±250 kV
Thermal transmission capacity	400 MW (2 x 200 MW)
Number of circuits	Bipolar link with metallic return cable
Number of power cables	2 power cables, one return cable
Number of fibre-optic cables	2, each with 48 fibres
Total length	244 km
Morvedre underground section	4 km
Undersea section	237 km
Santa Ponsa underground section	3 km

Floating devices and motor boats are used to keep the cable end afloat and direct it towards the coast in order to link up to the underground cable.

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