The electric crossing of the Messina Strait

In the 1950s, between Calabria and Sicily, was built an overhead electrical crossing span, which had no equal in the world in terms of the extension of the conductors and the impressiveness of the structures. An all-Italian record, from the design to the manufacture of the materials and to the construction, which should also be remembered for the brilliant and innovative solutions adopted.

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Editoriale Delfino

The history

The idea of a road link across the Strait of Messina has aroused the interest of Italian peoples through the centuries, from the Romans to the Carolingians, the Normans, the Bourbons and the newly formed Kingdom of Italy in 1860s. In the years between the two world wars, studies for an underwater tunnel were initiated, but these revealed enormous problems due to the poor solidity and the depth of the seabed. Conversely, the idea of building a long suspension bridge between the island and the continent appeared feasible, and has been proposed periodically; each time, provoking heated debates between the various national and local political factions, on its feasibility and convenience. To this present day, the bridge over the Strait of Messina remains an unrealised *millenary dream*.

The electrical connections between the two sides of the Strait have had better fortune. The first were the submarine telegraph cables laid, in September 1857, by the Bourbon engineer Jacopo Bozza, to complete the interconnection of all the stations in the Sicilian telegraph network with the mainland. The four-mile-long cable covered the distance between the hamlet of Cannitello in Villa San Giovanni and the hamlet of Ganzirri in Messina. Other underwater *telegraphic* cables were laid, in the early 20th century, between Punta Pezzo in Villa San Giovanni and Ganzirri and later laid in other areas of the Strait that are less troubled by sea currents.

The opportunity to transfer electricity from the continent to Sicily arose in the first half of the last century, after the Sila hydroelectric plants were commissioned. Their production, which was exuberant for Calabria's needs, could have reinforced the island's modest electricity potential of that time. Already in 1915, engineers Jona and Emanueli had proposed a three-phase 15 kV underwater cable insulated with impregnated paper that could carry a power of 15 MVA. In 1921, engineer Emanueli reviewed the study and proposed the use of six unipolar rubber-insulated 25 kV cables to make up two 20 MVA three-phase systems. But these underwater solutions were not considered reliable due to the harsh conditions of the seabed and the disturbing effect of the sea currents, an attitude that did not change even after the World War II, even though the technological progress had made available more robust cables capable of operating at voltages up to 150 kV.

The first project for an overhead line to cross the Strait of Messina also dates to 1921; it was presented by Engineer G. Ferrando at the 26th annual meeting of the Electrical Italian Association (AEI) which was held that year in Sicily. The study involved two three-phase circuits of 137 kV bare steel conductors capable of transferring a maximum power of 55 MVA. Each conductor was supported by two 277 m high guyed towers. The six towers on each side of the Strait were spaced by 112 m apart, as it was assumed that, on much longer spans than those constructed up to that time, large oscillations of the conductors would occur under the effect of the wind. This was a pharaonic project with a strong environmental impact, which would have given rise to many concerns, even at a time when less attention was paid to the aesthetic appearance of infrastructures. Experience of stringing and operating long spans, especially those crossing the river Po, had subsequently shown that it was not necessary to keep the conductors so far apart and that 20 m could be considered sufficiently cautious. 1936, both the Dalmine and Savigliano companies opted for a solution that greatly downsized the Ferrando project, while confirming the need for two circuits in order to cope with future developments in the Italian national electricity system. Each circuit could be supported at both ends by a single cable-stayed or self-supporting tower. The project was revised ten years later by the Società Anonima Elettrificazione (SAE), who came up with the idea of running the conductors at constant tensile load, a solution that would have made it possible to reduce the height of the towers by more than 50 m. This was a completely innovative counter-weighting system for power lines, even though it was already in use in cableways and in railway contact lines, on a much smaller scale. In addition, SAE considered the possibility of supporting both three-phase circuits with only one tower per side and demonstrated its feasibility during the development of the project. On this basis, the final project was elaborated and implemented (Figure 1) under the leadership of the Società Generale Elettrica della Sicilia (SGES).

Figure 1

The span crossing the Strait of Messina.

The site

The area of the strait of Messina, although splendid in terms of landscape and touristic attractions, has environmental characteristics that make it difficult to build infrastructures, whether they be bridges and overhead power lines or underwater tunnels and cables. At the most favourable points for sub-marine cable crossings, the Strait seabed reaches depths of up to 110 m and consists of sand interspersed with layers of conglomerates of poor consistency. In addition, the different timing of tides between the Tyrrhenian and Ionian seas produces strong currents that reverse their direction four times a day and in the narrowest areas, can reach speeds of some metres per second. The seismic risk (catastrophic earthquakes occurred in 1783 and 1908), the aggressive saline atmosphere and the constant presence of winds that could gust up to high speeds must also be considered. The latter makes the Strait of Messina 'the largest natural wind tunnel' in the Mediterranean Sea.

The route

The first plans considered the construction of the overhead electrical crossing more or less in the area where the first telegraph cables were laid, that is, where the distance between the two sides of the Strait is minimal, which would still have meant a length of the central span of about 3 200 m. A more careful topographical study showed that it was technically and economically convenient to locate the Calabrian support on a hill at Santa Trada, 166 m above sea level, even though this would have increased the length of the central span by about 400 m. The courage of the designers who accepted this further extension of a span already considered too long by many engineers is worthy of note.

The crossing

The final layout of the crossing (Figures 2 and 3) consisted of two three-phase circuits operating in alternating current of 50 Hz, at a voltage of 220 kV and capable of carrying a maximum total power of 300 MVA. The central span was 3 646 m long, sustained by two self-supporting suspension towers commonly called the pylons. The lateral spans of the crossing, 630 and 651 m long respectively, ended, on the Calabrian side, with low anchor stands and on the Sicilian side with two counter-weight systems. The elevation of the conductors was 204 m at the Sicilian suspension tower and 359 m at the Calabrian suspension tower; the minimum clearance of the conductors, imposed by the navy to allow the transit of any type of ship, was 70 m above sea level. The distance between the conductors was 25 m.

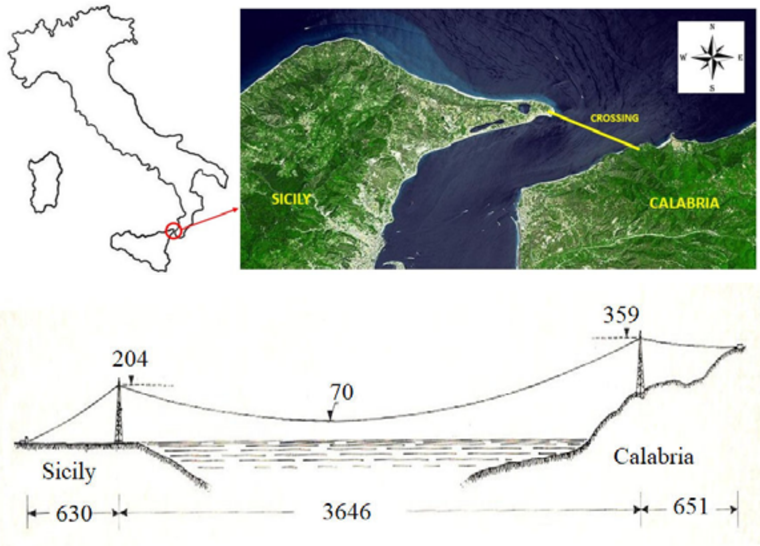

Figure 2

Profile and layout of the electrical crossing section of Messina Strait.

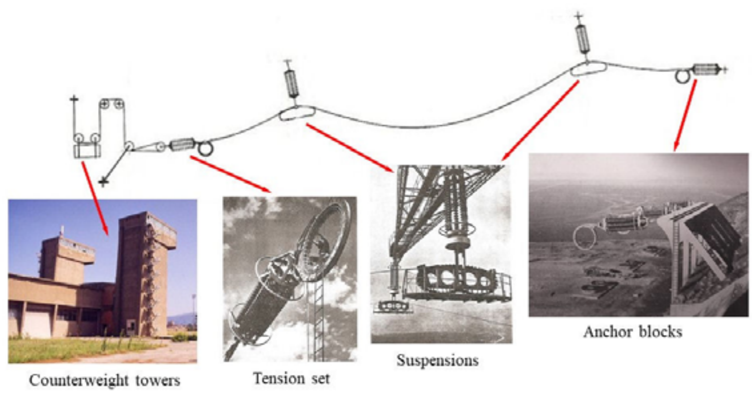

Figura 3

Profile of the crossing with main components.

The conductor

The choice of conductor was the subject of extensive studies and countless laboratory tests. The conductor had to meet mechanical, electrical and chemical requirements, which in many respects conflicted. It had to be able to withstand the high mechanical loads imposed by the design, have electrical characteristics suitable for allowing currents to pass through it without excessive heating and a corrosion resistance appropriate for the aggressive marine atmosphere in which it had to operate. It soon became clear that the use of steel was essential. Conventional steel conductors, copper welded steel wire conductors and steel-core conductors with aluminium wire outer layers were investigated, but none of the solutions met all the requirements. It was therefore necessary to design a special conductor (Figure 4), the construction of which was entrusted to the Redaelli company in Milan. It consisted of 19 strands (1+6+12), each composed of six steel wires wound around a central aluminium wire, evenly distributed inside the conductor, with the addition of six steel wires to increase the compactness and mechanical resistance of the conductor, reducing the gaps between the strands.

For corrosion protection, in addition to the galvanisation of the steel elementary wires, there was also heavy greasing able to withstand thermal cycling without dripping or percolation in a temperature range of -5 to 100 °C. The grease was distributed evenly inside the conductor by introducing it into the stranding cone during the assembly of the strands. However, it was cautiously estimated that the service life of the protection could not exceed 8 to 10 years and therefore, the conductors were to be replaced periodically. Perhaps the choice of conductor would have been easier if the aluminium-coated steel wire conductors (alumoweld) had been available, which appeared on the market in 1958 and which were only usefully employed many years later as shield wires and in other long span crossings.

Figure 4

The special conductor used in crossing the strait of Messina.

Foundations

The study of the foundations of the pylons suggested on the Calabrian side, a shift of a few tens of metres from the original position in search of more compact rock stratifications and, on the Sicilian side, the construction of an artificial reef to prevent the shoreline from receding towards the area occupied by the tower. The most common solution of four separate foundations, one for each foot of the tower, was not considered suitable to withstand the possible seismic stresses in the area and a monolithic foundation was chosen instead, consisting of a single large cross-shaped block, at the ends of which rested the four feet of the tower (Figure 5).

Figure 5

Foundation of the Sicilian suspension tower.

Towers and supports

Six Italian companies were invited to design the pylons for the central span. At the end, the choice fell on SAE, which was not only the most economical solution but also made it possible, with a limited increase in weight, to carry two three-phase circuits instead of the one originally planned. In addition, SAE gave ample guarantees to possess the capacity and the equipment to carry out the erection of the towers, including the foundations. The final version of the two almost identical self-supporting suspension towers of approximately 225 m in height (Figure 6) was a truncated pyramid shape with a square base, 50 m diagonal, and the lower cross-arms stretched across 75 m. The tower body members (Figure 7), made by welded latticed steel boxes, were protected from corrosion by painting. Each suspension tower was equipped with a service staircase consisting of 1 114 steps, starting from the foundations, and arriving at the extreme top of the upper cross-arms, as well as a lift covering the first 200 m. As far as the anchor supports are concerned, a simple trestle was foreseen on the Calabrian side with a sufficient height to guarantee the electrical clearance (Figure 8), while on the Sicilian side, the counter-weight system that characterises the entire work was installed. The counterweights (Figure 9) kept the conductors at a constant tension of 216 kN (about 22 tons), corresponding to 42% of their breaking load. Two counter-weight systems, one for each three-phase circuit, were housed in a pre-stressed concrete building (Figure 10). The whole crossing was designed to withstand seismic events of grade X on the Mercalli scale and winds of up to 150 km/h.

Figure 6

Pylons of the crossing span: a) Calabrian side, b) Sicilian side.

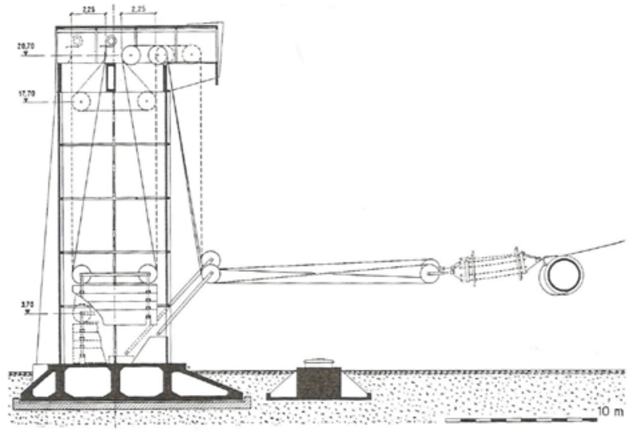

Figure 9

System of counterweights to maintain the constant tension of the conductors.

Figure 7

Latticed members of the pylons.

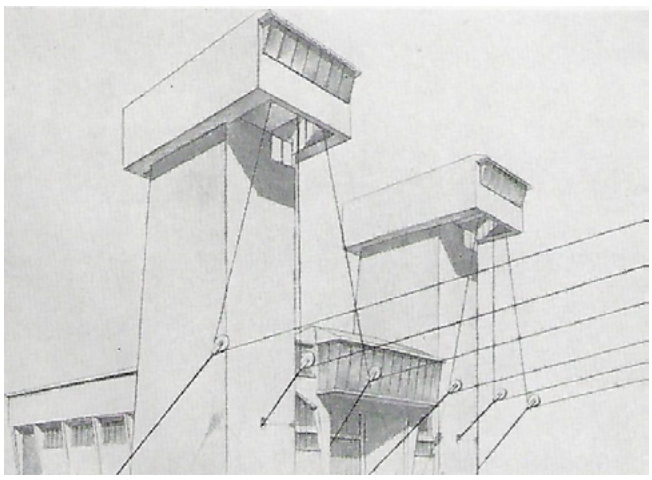

Figure 10

Building containing the counterweights.

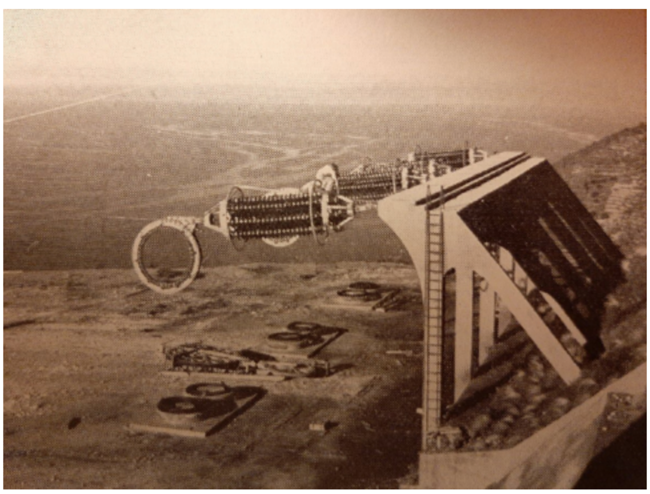

Figure 8

Anchors stand on the Calabrian side.

Suspension assemblies

After examining various solutions, a *tracked shoe* (Figure 11), designed and manufactured by the company Ceretti e Tanfani of Milan, with a virtual diameter of about 10 m, was adopted. This type of suspension saddle, as well as accompanying the conductors in their wide angles of exit from the supports, allowed them to be moved a few metres, when necessary, to relieve the mechanical stress on the most stressed points and, above all, facilitated their periodic replacement.

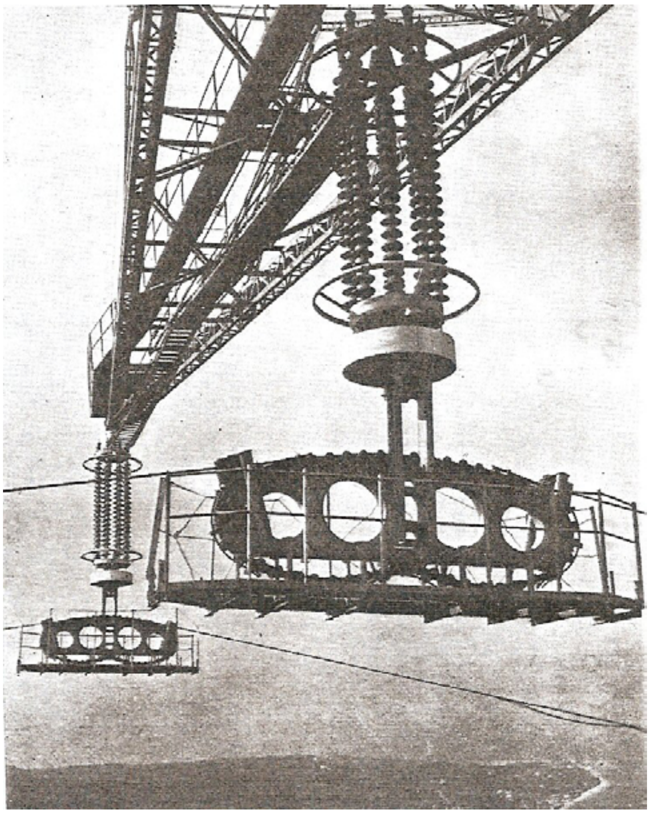

Figure 11

Suspension equipment.

Tension assemblies

Another innovative element was the tension assembly (Figure 12). Considering that conventional compression or bolted dead-end clamps would not have been able to withstand the loads imposed by the tension of the conductors, the choice fell on a solution that was common for cableways but never adopted for power lines. This solution consisted of large diameter (2.5 m) suspended drums, also made by Ceretti and Tanfani, on which were wound three turns of conductor that gradually transfer the load by friction.

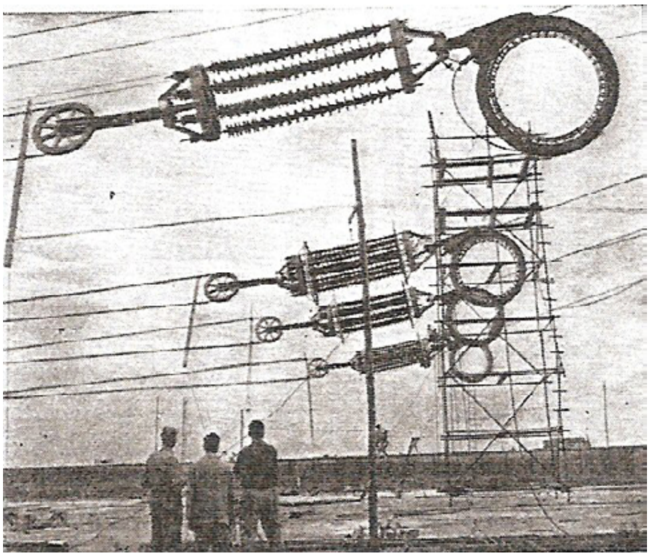

Figure 12

Tensioning equipment.

Insulators and fittings

The insulation of the electrically live parts from the structures, shown in figures 11 and 12, was achieved by means of cap and pin insulator strings, of the type used for normal 220 kV transmission lines, manufactured by the Richard Ginori company of Milan and the Società Ceramica Italiana of Laveno. In particular, twelve insulator strings in parallel, arranged in two concentric circles for the anchor assembly and eight strings arranged in a circle for the suspension assembly have been provided. A system of springs and equalizers ensured even load distribution between the strings and facilitated the replacement of damaged strings under tension. The insulator and conductor fittings were designed and manufactured by the Volpato company of Milan.

Stringing of conductors

The stringing of the cables was a complex operation, with many unforeseen events and some accidents. In order to allow smooth operations, the Strait was closed to navigation for 22 days from 14 July 1955. Unfortunately, during the laying of the pilot cables, an oil tanker that had not respected the naval blockade caused extensive damage to the installation. As a result, the laying of the cables was not completed at the end of the planned period. Since a second period of closure of the strait would not be possible for several months, it was decided to string the cables while the ships were on transit.

To prevent the conductors from coming into contact with sea water, the stringing under tension method, developed a few years earlier by the Edison Company of Milan, was used. However, the need for a precise synchronization between the puller and the tensioner, which are normally positioned each at one end of the section to be stringed, suggested bringing the two machines together on one side of the section (the Sicilian side) and using a pilot ring (designed by the Agudio company of Turin). The pilot cables were instead laid at the bottom of the Strait by two tugboats, an operation hampered by the continuous passage of ships and by some problems of the cables running around at the bottom, presumably against wrecks. The stringing of the first four conductors was completed on 22 September 1955.

Vibrations damping

The wind-induced vibrations of the conductors due to the effect of vortex detachment (von Karman effect) became apparent as soon as the pilot cables were strung, with worrying continuity and intensity. The constant presence of low-turbulence winds, and the high conductor tensile load which reduced its self-damping capacity, made the application of additional damping devices necessary. Stockbridge-type dampers (vibration absorbers capable of operating over a wide frequency range) were considered, as well as festoon type dampers which are based on the principle of transferring vibrations to stranded cables that are not under tension and therefore have greater self-damping capacity. The initial choice was for the festoons, which were made from pieces of the same conductor used for the phases and arranged as shown in figure 13. After a few years, however, fatigue failures occurred in the conductors near the festoon clamps, which were then replaced by Stockbridge-type vibration dampers manufactured by SALVI of Milan. Since the spectrum of vibration frequencies was too wide to be covered by a single type of damper, two complementary types were designed (Figure 14):

1. the basic model (2x4R11) capable of operating in the frequency range of 5-60 Hz
2. the 2x4R5HF model designed for operating over a higher frequency range of 13-112 Hz.

Given the large amount of vibrating energy to be dissipated, the dampers were designed in a twin formation, i.e., consisting of two identical dampers, in parallel, fixed to a steel C-shaped channel carrying the connecting clamp to the conductor. Six dampers (four basic units and two HF units) were installed at each end of both the central and side spans and positioned as shown in figure 14. However, after four years, failures of some conductor elementary wire were discovered on two phases near the outmost damper of the central span at the Sicilian side. Laboratory tests showed that the failures were caused by the excessive weight of the steel channel, which did not allow the dampers to move at high frequencies. Analytical calculations, carried out with the first calculation programs dedicated to studying the aeolian vibrations of overhead conductors, confirmed that the same dampers in single, rather than twin, configuration would be able to control the vibrations within limits that would not accumulate fatigue cycles on the conductors. Single dampers replaced the twin dampers with an unchanged sequence but shifted one metre towards the centre of the span so as not to insist on conductor points already stressed.

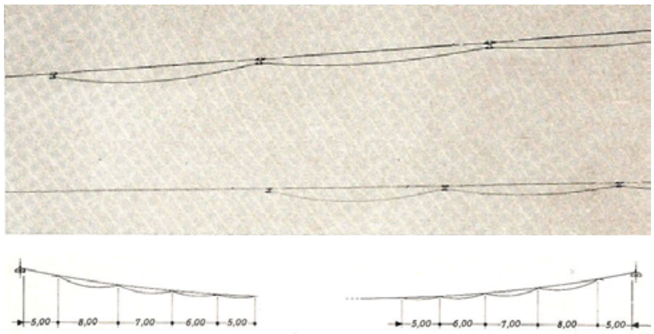

Figure 13

Anti-vibration festoons and their distribution in the central span.

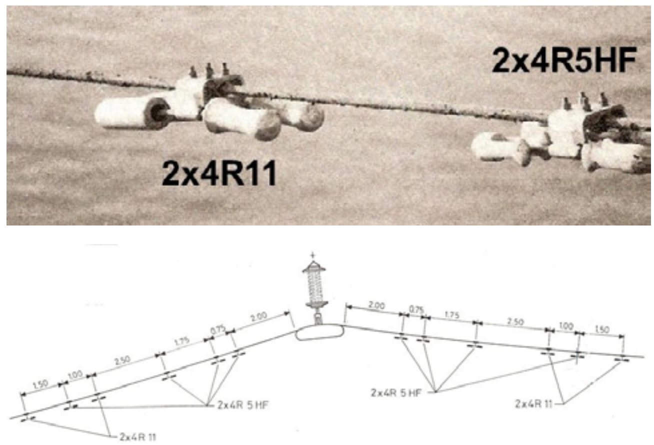

Figure 14

Stockbridge type vibration dampers used in the spans of the crossing and their distribution on the conductors.

The inauguration

In November 1955, the crossing was presented to the CIGRE study committees that were meeting in Italy that year (about three years had passed since construction began). The crossing was put into service on 27 December 1955 and the official inauguration took place on 15 May 1956.
In 1957, the Italian National Association of Architects and Engineers (ANIAI) awarded the prize for the best Italian engineering achievement to the electrical crossing of the Strait of Messina. The prize was in its second year: in the previous year, it had been awarded to the design of the Cristoforo Colombo liner, twin of the ill-fated Andrea Doria, the two liners considered at the time to be the most beautiful in the world.

Operation and decommissioning

The crossing remained in service for 38 years. For the first few years, only four conductors were used, making up a three-phase circuit, 150 kV, plus a spare conductor;

in 1971, two more conductors were installed, completing the two originally planned circuits, and raising the voltage of the connection to 220 kV. The last conductor replacement was carried out in 1980. In 1985, four submarine cables went into service, permanently connecting the 380 kV transmission grid on the mainland with the Sicilian grid, with a transport capacity of 1 000 MVA. The overhead crossing then lost its importance, and its dismantling was considered due to its high operating costs. However, after extraordinary maintenance of the structures, the crossing was kept in service for another 10 years and was finally decommissioned in 1994. The conductors and armaments were removed, leaving only the towers (Figure 15), which are now part of the landscape and bear witness to a major engineering achievement that would still be considered one of the world's greatest overhead crossings. The Italian Electricity Board, ENEL, donated the two pylons to their respective municipalities: Messina and Villa San Giovanni, who are responsible for their maintenance. The municipality of Messina, on the occasion of the Great Jubilee of the year 2000, created an artistic lighting system for its pylon, which at night offers a suggestive spectacle.

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Notes

1. The dimensions shown in the figures are in metres.
2. The black and white figures have been taken from publications (1) and (2)

Figure 15

Current condition of the pylons.