# Elba Island - Integrated operation of the High Voltage submarine connection with innovative techniques


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***Abstract*— The Island of Elba is connected to the national transmission grid (RTN) through the 132 kV line CP Piombino Cotone - CP S. Giuseppe; the current connection and the energy demand of the island, which recorded a significant increase during the touristic summer season, do not meet the security criteria. Since 2011 Terna, Italian Transmission System Operator, included in the National Development Plan the project to connect island to the Italian Peninsula through a second high voltage cable. Pending the authorization and realization of the second line, new initiatives, technologically innovative, have been implemented to mitigate the exposure to energy load losses. This present document illustrates the technological choices made and their operation.**



**Keywords— National Transmission Grid, Energy not Supply, Primary substation (CP), substation (SE), Elba Island HV network**


## I. Introduction

The Island of Elba is connected to the National Transmission Grid (RTN) through the 132 kV line CP Piombino Cotone - CP S. Giuseppe, consisting of a mixed line submarine and overhead. The current connection and the energy demand of the island, which recorded a significant increase during the touristic summer season, do not meet the security criteria; for this reason, since 2011 Terna, Italian transmission System Operator, included in the National Development Plan the project of a second HV Cable, called "ELETTRODOTTO 132 kV ELBA – CONTINENTE" [1].

The paper describes the measures that have been put in place in order to mitigate the existing operational critical issues; in particular:

- Section II: deals with the electricity power system of the Elba Island in terms of grid connection, demand, production, coordination between TSO and local DSO and expected developments.

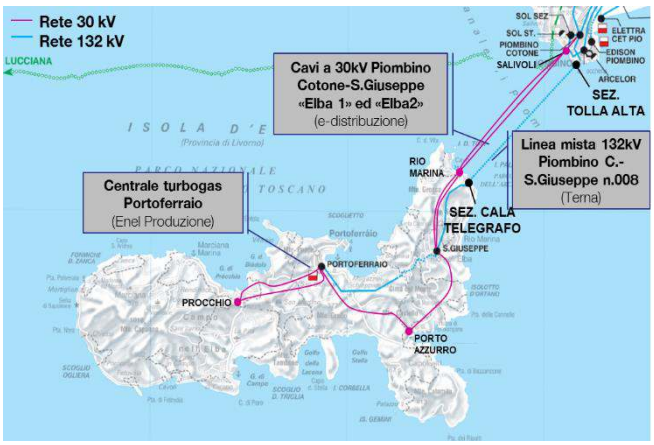
- Section III: deals with the installation and logics of a dedicated protective system for optimizing of voltage raises on the new (renewal) Terna substation located on the HV cable

- Section IV: deals with the complete revamping of the fluid oil pressurization system "Brizio Basi Technologies" (third installation in Europe) [4]

## II. Elba Island HV Power System

As shown in Figure no.1, the 132 kV electricity system of the Island of Elba is connected to the National Transmission Grid by line 132 kV CP Piombino Cotone - CP S. Giuseppe (mixed line consisting of: CP Piombino Cotone - SE Tolla Alta 2,0 km overhead line; SE Tolla Alta - SE Cala Telegrafo 11,8 km, submarine and underground cable, SE Cala Telegrafo - CP S. Giuseppe 5,3 km overhead line) connecting the two CP owned e-distribuzione (local distribution company), the first on the mainland (Piombino Cotone) the second on the island (CP S. Giuseppe). Interposed between these two CPs are the two high voltage stations owned by Terna: Tolla Alta (in the municipality of Piombino) and Cala Telegrafo (Rio Marina, Elba Island).

Fig. 1. Medium and High Voltage network in Elba Island.



The network is operated through a 132 kV radial connection in normal condition and in case of fault or planned outage:

- Two feeder 30 kV of property of the DSO characterized by ancietness and performance limitation
- Portoferraio power plant, operating mainly on request Terna (contracted from 1 June to 30 September, significant cost and limitation on the maximum number of hours of usage, 500 h/year).

The load of the island of Elba is not always fed in condition of full reliability as, in case of unavailability of the only connection RTN 132 kV, "Piombino C. - Tolla Alta - Cala Telegrafo - S.Giuseppe", the existing cables in MT connection with the mainland and the Portoferraio Power Plant fail to cope with the full power required in peak conditions; an emergency plan shared between TSO and DSO is activated in the most severe situations according to the following scheme.

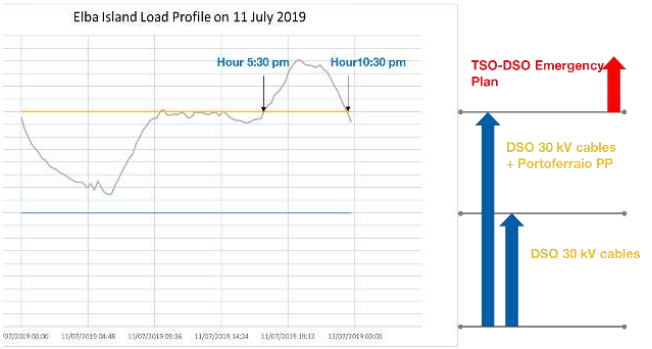



Fig. 2. Elba Island Load Profile on 11 July 2019

For this reason, Terna, taken over of the 132 kV link "Piombino C. - Tolla Alta - Cala Telegrafo - S.Giuseppe" in 2010, has planned a second submarine cable link in its National Development Plan 2011, to reach the following benefits:

- Increase quality and security of service
- Reduce network losses
- To reduce the costs arising from Portoferraio power Plant and of $CO_2$ emissions related
- To ensure that requirements are met in safety, take in account the increasing of load and the evolution of the electrical system.

The project [1] consists in a second 132 kV power line connecting the island, (Portoferraio) to the mainland (primary cabin in Colmata, Municipality of Piombino, prov. of Livorno).
In 2021, the project has been authorized by the Ministry of Ecological Transition [2]. The link will be 37 kilometers long: 34 of those will be undersea cables at a maximum depth of 70 meters and over 3 kilometers will be completely underground.

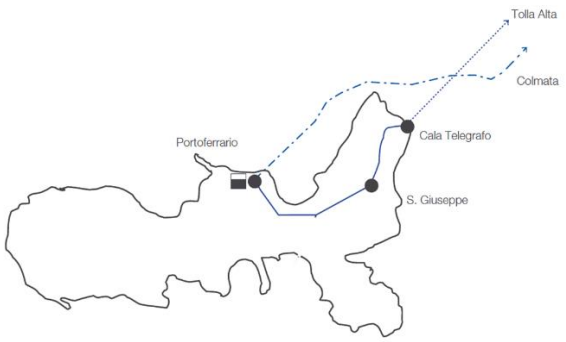



Fig. 3. Framing of the new Project AC 132 kV CP Colmata – CP Portoferraio

## III. MITIGATION ACTION: NEW DEDICATED PROTECTIVE SCHEME

Starting from 2015, in the face of the authorization delays of the grid reinforcements described in the previous paragraph, a series of interventions aimed at a significant renewal were implemented by Terna aimed at maximizing the reliability of the connection.
Among the main installation works carried out, the implementation of a protection system for faulty section discrimination. The first non-invasive and useful project (*capital light*) was to limit damage in the event of a breakdown (oil spills, further damage to cables in the event of a breakdown, e.g.). This could be achieved by installing a protective system (overcurrent relay) discriminating in which section of the line the fault occurred.
The submarine cable section between SE Tolla Alta and SE Cala Telegrafo is made up of 4 single-core cables: three for ordinary operation (current), the spare quarter for replacement in the event of a breakdown (hot reservoir).
The four cables are periodically rotated to obtain an equal aging of the three phases (aging due to the passage of current in the conductors and due to insulation stress). The submarine cables are also equipped with a fault recognition system based on the passage or not of short-circuit current at the Tolla Alta and Cala Telegrafo terminals. With reference to the following figure:

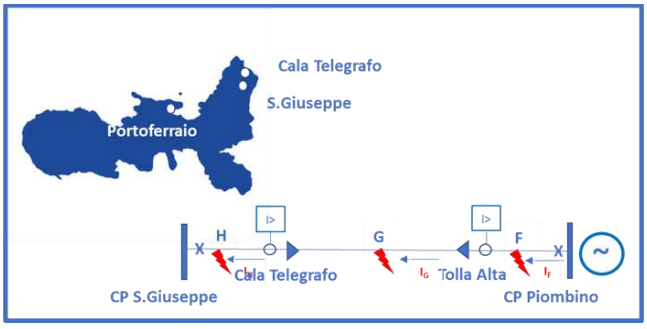



Fig. 4. The existing line 132 kV Cp S. Giuseppe line electric scheme

The detection of fault current transit is entrusted to the overcurrent relay installed on each phase at both SE Tolla Alta and SE Cala Telegrafo and adjusted in such a way as to be sensitive to the short-circuit currents supplied by the RTN behind Piombino (mainland) in the 132 kV grid on the Island

of Elba while remaining inactive under grid load and overload conditions.

There are 3 distinct fault situations [3] from short circuits at points F, G and H of Figure 3

a. *Failure in the section of the terrestrial network of the Island of Elba (failure H):* both A and B relay will activate indicating the presence of an external fault with the submarine cable

b. *Failure in the continental air network section (fault F):* none of the A and B relay will activate indicating, once again, the extraneousness of the cable to the fault event in progress in the network.

c. *Failure in the submarine cable between terminals A and B.* In this case, only one of the two overcurrent relays will activate (the one placed in A) while the second relay (the one placed at the end B of the cable will remain inactive.

In all the situations considered, the status signals of the current detectors are processed by a centralized logic physically located in SE Tolla Alta which in cases a) and b) will allow to signal the absence of the fault in the submarine cable (the most vulnerable part of the link). The signal does not only concern the presence of a fault but will also indicate which of the three phases is the one affected by the fault (phase 4, 8 or 12).
The described automation does not automatically open the switches at CP Piombino and CP S. Giuseppe; this will be done by the line protections installed; on the basis of the recognition of the faulty cable and the recognition of the out of service status of the power line by opening the switches at the ends, activates the out of service logic of the faulty cable, allowing the North East Control Room Center of Terna to remotely replace the cable with the spare one, thus allowing a more fast recovery of the island's power supply service.

## IV. MITIGATION ACTION: INNOVATIVE REVAMPING INTERVENTION OF THE FLUID OIL PRESSURIZATION SYSTEM (BRIZIO BASI)

### A. *Context before revamping*

The 4 cables are oil insulated at 10 Bar pressure with natural special fluid “oil” (dodecylbenzene - $C_{12}H_{25}C_6H_5$). In the continental substation a tank and a control system check the pression in normal operation condition, while during fault the system must partialize the flows in order to reduce damages on the cable. The pressure is also dynamically controlled in relation to the current flowing in the link and, so far, to the temperature of the cable.
The original fluid oil pressurization system dates to the mid-1980s and was built by PIRELLI JEROME, INC. (South Carolina, US). The mechanically very robust plant installed a technology at the forefront of the time that has brought it up to the present day. The new requirements in terms of remote controls and automation, the request for greater precision and reliability led Terna to decide to upgrade the system.

### B. *Temporary oil puping bypass during system renewal*

The strategy applied and agreed with Terna/Prysmian to allow the implementation of the new systems, involved the installation of a temporary parallel electrical/electronic system that managed the 132 kV cable leakage pumping and control system suitable for both the plant crossover on the island and for the pumping station on the mainland. The system remained in operation monitored h24 by technicians for the entire duration of the work. The intervention began on the island for a logistical issue, ending with completion on the mainland. The only out of service necessary for the calibration and testing of the alarms was agreed, programmed, and piloted with Terna personnel, the overall duration was 5 working days.

### C. *Description of the new sensors and actuators including flow switches and what they allow to do*

The new system implements the best of technology regarding management electronics and automation. In addition to optimizing the flow of fluid in the cables, it has reduced electricity consumption and the noise level of the station pumps by 50%. The new bi-directional flow monitoring system uses mass measurement technology to replace the volumetric one which was affected by the fluid temperature. The new system is wear-free as it has no moving parts. The new vacuum pumping unit uses very quiet and leak-free magnetic drive pumps as it does not have seals subject to rotation of the motor shafts. The cable pressurization pumps now run at a speed of 50% slower, they are controlled by inverters for an electrical consumption proportional to the actual effort for a longer duration and thermal efficiency.

Fig. 5. Overview of the new control system and hydraulic components in Tolla Alta (Piombino)

The monitoring and management system allows to regulate flows and pressures in a completely automatic way even with the variation of the load of the cables and of the ambient temperature.
The two stations of Tolla Alta and Cala Telegrafo are constantly connected with a data exchange system that uses an optical fiber, the integrity of the connection is constantly monitored by the 2 CPUs that play to exchange bits even when the system is in standby, the any absence of response generates an alarm which is sent back to the remote control.
The system is perfectly capable of operating even without connections between stations (disaster recovery routine).
These new communication frontiers allow total management by remote technicians, both locally, i.e., the station on the

mainland can view the status of use and give commands to the station on the island, as well as the other way around.
But above all the technicians, including the manufacturer, can intervene remotely in compliance with the Cyber Security regulations.
It is possible to check the operating status, the state of use, maintenance and intervene with corrective measures to assist the local staff perfectly in line with the current standards for 4.0 systems.


Fig. 6. Pressure level and setting overview of the system visible in both terminal substation and in remote mode from everywhere

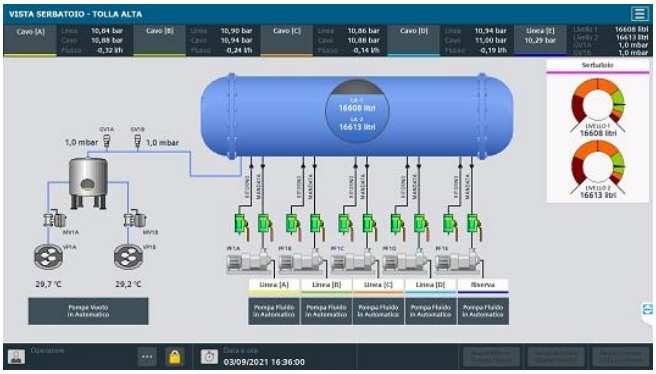




Fig. 7. (above) Overview of the thank in Piombino and (below) pressure truck records of the loaded cables in the new system. All the data can be monitored by remote.

Brizio Basi in collaboration with Prysmian used, for this project, a tried and tested method of intervention that led to compliance with the agreed times and costs foreseen up to now used 3 times in Europe and 6 times in the world.

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