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First experience with factory-coated glass insulators on the Italian transmission network

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First experience with factory-coated glass insulators on the Italian transmission network

- **General**
- TERNA's experience and need of an industrial approach
- Set-up of the factory process
- Type tests
- Criteria for the selection of lines to be equipped with coated insulators
- Recent installations
- Methods of installations
- First outcomes
- Future programmes and conclusions

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General

- Attention of electric companies to the reliability and availability of transmission lines as well as to parameters related to the quality of the electric service .
- Present market regulations that highly reward/penalize the performances of the electric system with respect to the targets established by the control authorities.
- Specific attention to surface insulation, the risk of decay of which usually depends on local pollution levels associated with meteorological conditions that sometimes can hardly be predicted
- Insufficience of the specific creepage concept, as confirmed by IEC 60815, that clearly recognizes that, in the case of exceptional pollution severity, even a specific nominal creepage of 31 kV/mm and above may not be adequate and alternative measures, like washing and greasing, may be necessary

General - Problems and countermeasures in ITALY

- Large extent of costal areas characterized by no rain in the summer, exposed to strong sea polluted winds and subject to condensation at the end of the dry period.
- Recent events, among which it is worth mentioning the black-out of Sardinia Island on September 2001, caused by exceptional marine pollution conveyed by north-west wind as far as the middle of the island, at long distance from sea coast.
- Necessity to apply any available methods to reduce the risk.
- Accurate mapping of the areas associated with different pollution level,s based on both meteorological records and field experience (GIS technology).
- Classification of transmission lines according to their technical characteristics and importance for the national transmission system in the most critical areas

More than 15.000 km of lines with nominal voltages ranging from 132 to 380 kV in heavily polluted areas, about 1.800 km of which in very heavily polluted or exceptionally polluted areas, with salinity level of 112 g/l and above.

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General - Problems and countermeasures in ITALY

Available tools:

- Selective inspection
- Predictive models based on meteorological records
- Predictive models based on monitoring of the conductive deposit
- Optimisation of creepage distances
- Extensive installation of composite insulators
- Conventional washing and greasing
- Washing from helicopter
- Live line washing
- ……....

In this framework, the emergent technology of insulators covered with RTV coating seemed to offer the possibility to meet the mechanical reliability of the toughened glass insulators with the efficiency against pollution of the polymeric materials, while keeping live line work and safety practice intact.

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Previous TERNA's experience with silicone coating

- Laboratory tests performed in the 90's, for a preliminary analysis of the coating material.
- First pilot installation of coated insulators realized on 132 kV lines in North Sardinia, where insulators used to be regularly greased.
- First application aimed at solving a real case of O&M realized in 2003 on the 380 kV line connecting the "Brindisi North" power plant to the Brindisi substation, in Puglia, South-East of Italy.
- Coating applied in situ by hand-spraying it.
- Poor results, mainly because of:
  - Waste of material
  - Inefficiency of the process
  - Poor surface appearance
  - Poor quality of coating
  - Non-uniform distribution of the coating thickness
  - Particular difficulties in spraying the lower surface of the insulators
  - Objections of workers because of vapours inhalation
  - Pollution of the surrounding field because of wasted silicone……
- Further attempts were repeated in order to improve the efficiency of such manual application, but the conclusion was that only an industrial approach could solve the problem.

TERNA's decision to involve a major manufacturer, capable of producing coated insulators under a fully controlled process.

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Set-up of the factory process

Main steps for this process (besides the qualification of a silicone compound):

a) Cleaning

b) Coating and curing

c) Packing, storage and transport

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Set-up of the factory process

a) Cleaning:

- Critical importance of surface preparation prior to applying any coating for the overall quality and life performance.
- Necessity to define basic acceptance criteria (one of them is the adherence of the silicone film itself on the glass beneath).
- Immediate evidence of direct relation between cleanliness of the surface and adherence property.
- Necessity to improve the cleaning process and standard practice recommended by silicone compound manufacturers.
- Necessity to optimize solvents for cleaning.

Quality of the adherence largely improved, providing a much better and consistent bonding between glass and silicone compound, as proved by factory tests

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Set-up of the factory process

The “comb scratch” adherence test as a very good indicator of adherence (tool described in ISO 2409 standard).

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Set-up of the factory process

b) Coating and curing:

- Coating applied by spraying the compound in multiple steps to achieve the correct thickness (> 300µm).
- Spraying parameters as a function of the type of silicone, viscosity…
- Necessity to control the loss of silicone during spraying given the high cost of the raw material.
- Factory coating procedure, progressively moved from manual operation to semi-automatic spraying
- Curing temperature, humidity, time and drying conditions evolved over the last two years, based on experience and quality inspection on coated products.
- Possibility of a further evolution towards a fully automatic process.

Set-up of the factory process

c) Packing, storage and transport

- Risk to damage the coating either in the factory or during transportation and installation
- Importance to supply the insulators in excellent condition
- Necessity to modify traditional methods of packing and storage

Use of styrofoam boxes and vertical storage of strings

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Set-up of the factory process

inside protection of a coated insulator box

shipping arrangement of crates with coated insulators

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Type tests

In the absence of national and international standards for factory coated insulators, TERNA's technical specifications were originally conceived as a merge of the available standards for glass and composite insulators, with the necessary integrations relevant to the silicone coating technology, such as composition of the raw material, coating thickness, methods of application, …….

In the following, based also on the feed-back from manufacturer and field experiences, the first draft was duly revised and the prescribed parameters and tolerances optimised so as to meet the required performances with the industrial feasibility.

As a result of this mutual feed back from client and manufacturer, a body of technical prescriptions is available now, that includes:

- Thickness requirement and tolerances
- Adherence criteria
- Flammability characteristic
- Ageing cycle test (2000h)
- Power arc test
- Salt fog withstand test
- Material verification
- ……..

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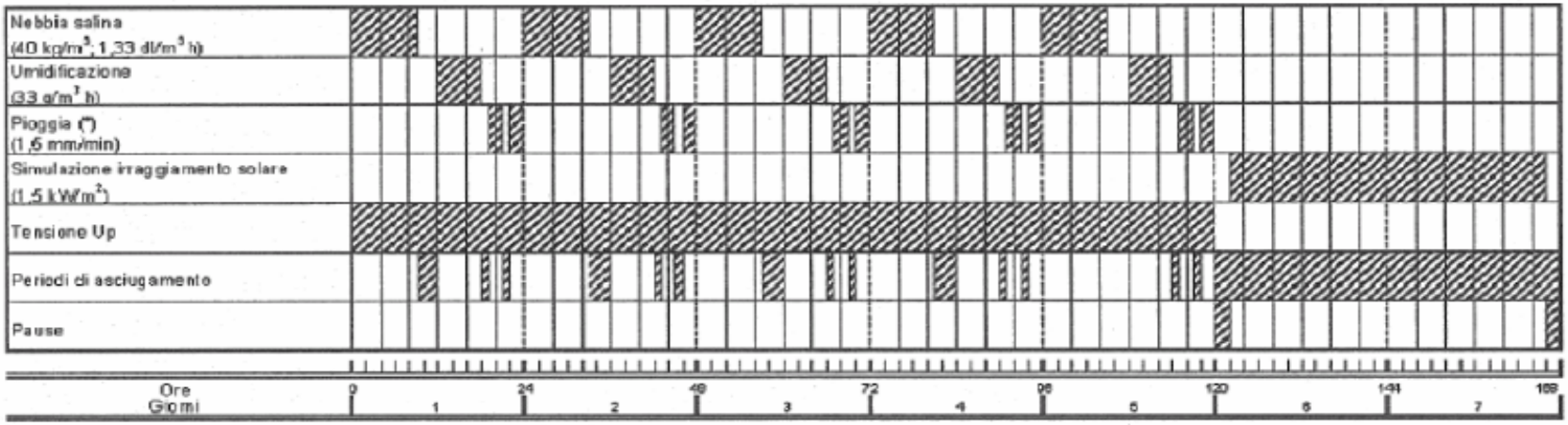
Type tests - the 2000 hour ageing test



2000 hours ageing test as prescribed by TERNA's technical specifications

Acceptance criteria:

no erosion or tracking marks and no more than 3 flashovers during the entire sequence

Test results

no degradation was found and no flashover at 40g/l occurred, as stipulated in the procedure

Monitoring of the current during the entire duration of the test has shown some evolution of the leakage current, without, however, producing any condition close to a flashover

(e.g.: the vertical string had little evolution of the current, fluctuating from 0.75mA peak at the beginning to 0.9mA peak at the end of the test. The horizontal string went from 0.34mA peak to a maximum of 1mA peak at the end of the salt fog sequence, sign of a reduction or temporary loss of hydrophobicity. In the other parts of the cycle, the current was fluctuating between 0.4mA and 0.9mA depending upon the step in the cycle).

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Type tests

Controls and test chamber for TERNA 2000h ageing test performed at Saint Yorre Laboratories

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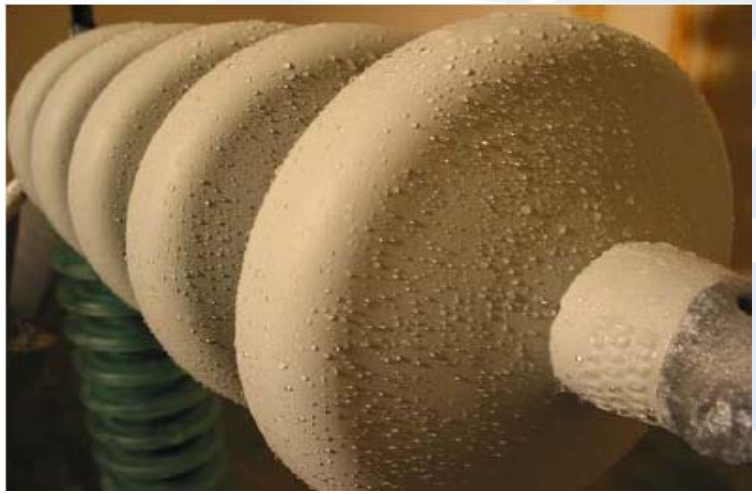
Type tests

Vertical string after the test



good hydrophobic behaviour after completion of the 2000h ageing test

horizontal string after the test

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Criteria for the selection of lines to be equipped with coated insulators

- Comparison of costs of different technologies (costs of initial installation + costs of substitutions and/or washing/greasing treatments necessary in a typical life-cycle of 30 years)
- Analysis of possible benefits in terms of pollution efficiency and mechanical reliability.

material	initial installation	substitutions	washings greasing	pollution efficiency	mechanical reliability	cost	diagnostic methods
toughened glass	1	=	14	limited	Extremely high	low	no risk
composite insulators	1	1	=	high	High	low-medium	research in progress
RTV coating	1	2	=	high	Extremely high	high	no risk
life cycle 30 years							

Main parameters for a technical-economical comparison of insulator types

Present TERNA's guidelines:

- In areas with pollution levels from "heavy" to "exceptional", coated insulators recommended for lines of first priority (e.g. lines necessary for black start, lines without redundancies,….).
- Similarly, with regards to lines of lower priority, coated insulators recommended for critical crossings (railways, motorways,…).

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Recent installations on the Italian network

In accordance with the above recommendations, a large programme of installation was launched in 2005.

Type \Year	2005	2006	2007	Total
U 70 AS RTV	2.910	24.005	4.392	31.307
U 120 AS RTV	39.579	21.721	24.912	86.212
U 160 AS RTV	5.320	13.860	8.361	27.541
U 210 AS RTV	10.280	16.832	3.662	30.774
Total	58.089	76.418	41.327	**175.834**

Type and number of RTV coated insulators installed in the years 2005-2007

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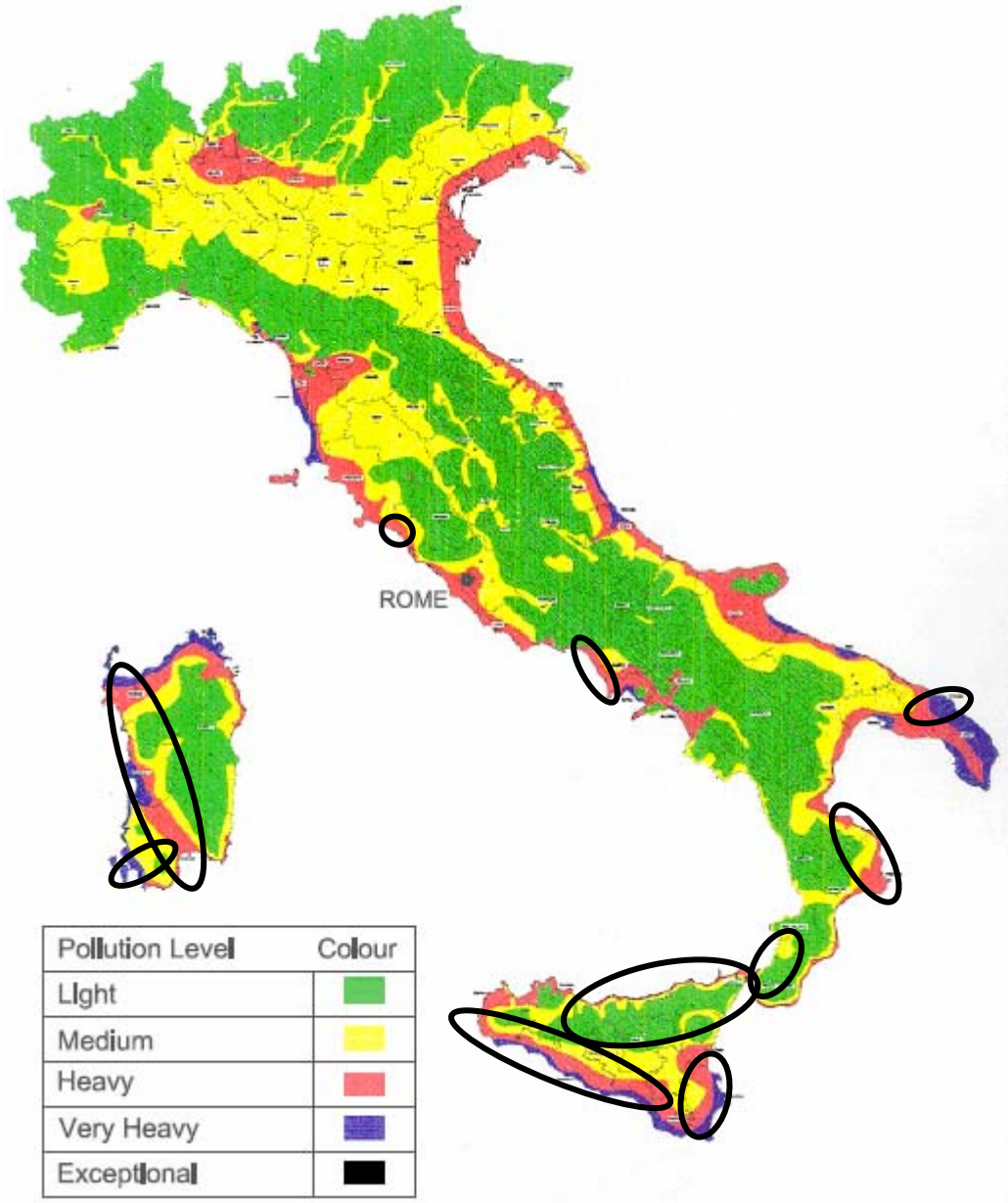
Recent installations on the Italian network

Geographical map of pollution and location of the lines equipped with factory-coated insulators.



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Methods of installations

Basically, the installation of coated insulators should not involve any changes in current working methods. In practice:

- In the case of conventional methods of installation (line out of service), some additional care proved to be necessary when handling the strings, in order to reduce the risk of damages of the coating due to contacts with tower members and line materials. However, in the majority of cases, such damages are purely aesthetic, without any real effect on the pollution efficiency.

- Such risks do not exist in the case of live line working, owing to the specific procedures and tools (cradles, insulating rods and ropes, ……) that are used to prevent any infringement of the electric clearances and that also prevent, as a consequence, any contact between components parts during lifting or positioning.

Methods of installations:conventional methods

Coated anchor strings installed on a 380 kV line in the proximity of the Mediterranean coast, North of Rome.

Minor scratches produced during the installation may be noticed.

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Methods of installations: live line work

Installation of coated insulators on a 220 kV live line in Sicily, South of Italy

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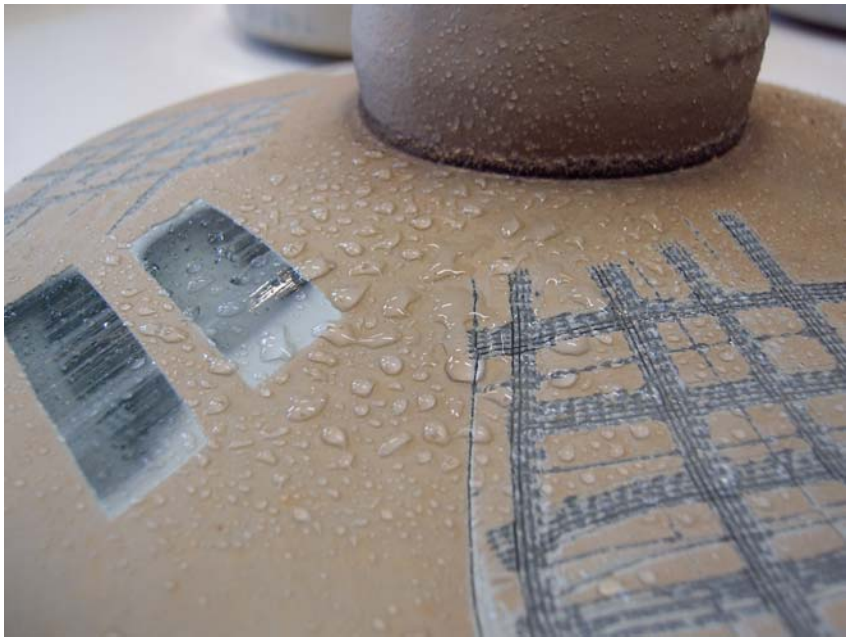
First outcomes

- Although it is quite evident that 2-3 years of experience are not sufficient to reach definitive conclusions, the first outcomes are certainly encouraging.
- In no cases extra washing was needed during this first operation period.
- In the same period, no outages were reported.
- Insulators taken down from a 220 kV OHL were tested and compared to insulators that were kept in a warehouse for a similar time. The adherence proved to be still excellent, while hydrophobicity remained good (contact angle above 110°)



Adherence and hydrophobicity tests on insulators removed from a 220 kV line after two- years operation cycle

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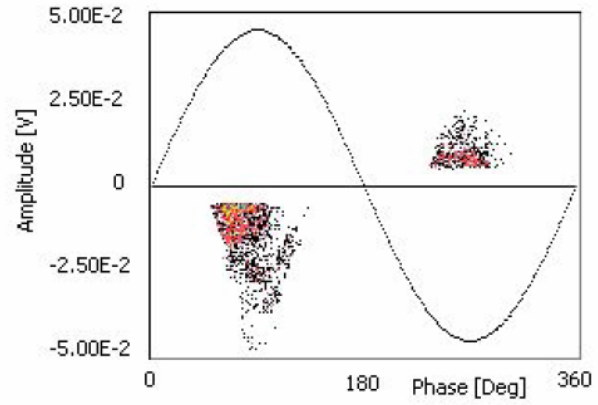
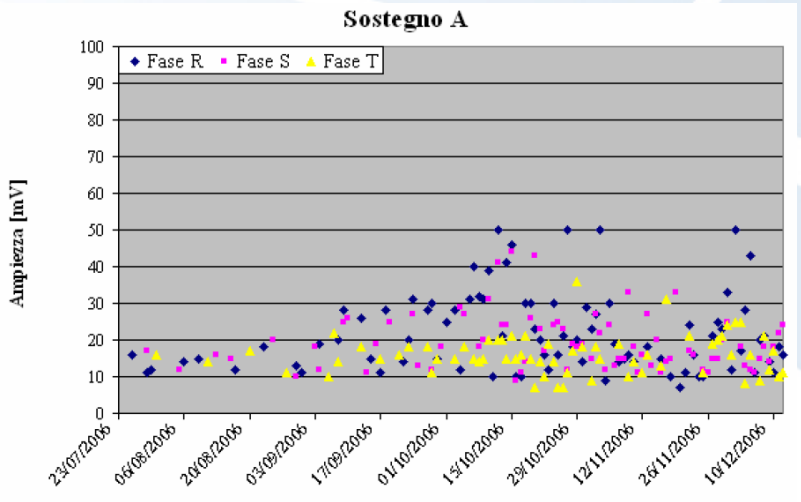
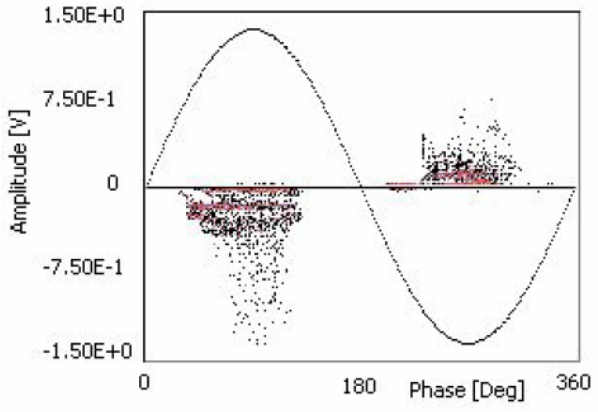
First outcomes: monitoring of 220 kV OHL Brindisi Pignicelle

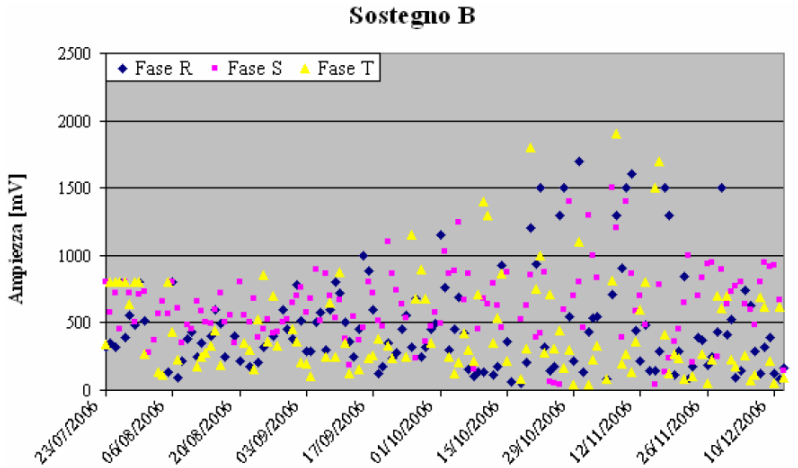
PD measurements on RTV coated insulators





PD measurements on normal glass insulators





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Future programmes and conclusions

- Great technological efforts and noticeable investments have permitted the set-up of an industrial response to the request for RTV coated insulators.
- A sound industrial product is offered now to the utilities, with excellent repeatability, consistency and quality, not achievable at the same level when coating application is done in the field.
- Based on a comprehensive experience that has covered all the relevant industrial aspects, ranging from manufacturing and testing to installation and operation, this technology can be utilized whenever a total mechanical reliability and a high insulation efficiency are required, also considering the need of live line work in full compliance with established safety standards.
- The first outcomes from the field are positive: no outages have been reported and the laboratory tests performed on insulators removed from lines after the first operation period are very encouraging, no real decay has been shown.
- The cost/benefit analysis will also benefit from a more precise assessment of the life- cycle of the RTV coating, that is goal of the long term monitoring programme started by TERNA and SEVES-SEDIVER
- However, this technology is still suffering from higher production costs if compared with other technologies, and this is representing the actual limit for its application.
- Costs would certainly benefit from a broader market, but, a further revision of the whole production process seems necessary.
- Such revision should firstly start from the production of the coating material, that still represents the major part of the total cost.
- In the meantime, the authors are suggesting that the technical specifications that have been prepared by TERNA and thoroughly revised by SEVES be the reference for a normative project to be put forward at international level.

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