EVALUATION OF THE INSULATOR SURFACE POLLUTION AS A TRIGGER FOR CLEANING OPERATION

Paolo Omodeo, CESI RICERCA – Italy
Ezio Panzeri, CESI RICERCA – Italy
Giuseppe Rizzi, CESI RICERCA – Italy
Claudio Valagussa, CESI RICERCA – Italy
giuseppe.rizzi@cesiricerca.it

ABSTRACT

*The paper reports the description of a new system AMICO II (**A**rtificially **M**oistened **I**nsulator for **C**leaning **O**rganisation) aimed to measure the surface conductivity of a probe insulator in view of the assessment of the criticality level of the station insulators. Moreover, the results obtained in the first year of field trial are reported. This work has been financed by the Ministry of Economic Development with the Research Fund for the Italian Electrical System under the Contract Agreement established with the Ministry Decree of March 23rd, 2006.*

INTRODUCTION

One of the goal of any Electrical Utility is to guarantee a very high availability of its network. In turn, the availability depends on several factors as for example the service load cycle, the components design, the maintenance and diagnostic procedure and the investments. With the aim to reduce the cost and improve the efficiency, the most advanced Network Operators are moving from time based maintenance towards a condition based maintenance at least for the most important components.

For line and substation insulators the possible diagnostic indicators should highlight both variation of electric field caused by defects and reduction of the withstand voltage due to surface pollution.

The possibility to schedule the cleaning operations of insulator surface at the proper time is very useful for the reduction of both the maintenance costs and the risk of outages. At the purpose some diagnostics systems were proposed in the last decade, based on the measure of different indicators such as Equivalent Salt Deposit Density (ESDD), surface conductivity and leakage current. AMICO II system, described in the paper, is based on the measurement of the surface conductivity of a probe insulator.

CHARACTERISTICS OF AMICO II SYSTEM

The basic idea of AMICO II system is that a probe insulator, located close to the insulators to be monitored, is subjected to the same environmental pollution and the mechanism of pollutant accumulation can be assumed equal for probe and insulator to be monitored. Under these conditions, the severity level of the pollution layer determined for the probe insulator can be extended to the insulators to be monitored. AMICO II performs the measurement of the leakage current of a probe under the actual weather and inducing the condensation of the ambient humidity on the insulator surface by means of an artificial cooling down process. This latter condition simulates the worst possible situation with the actual pollutant deposit anticipating the possible natural humidification.

From a practical point of view, once installed AMICO II system on the site to be monitored, it is necessary to schedule the measurement (time and type). Typically, the leakage current (surface conductivity) under actual weather condition is measured every hour, while the measurement under forced surface humidification is measured once per day: at sun rise during summer and in the afternoon in winter to avoid Dew Point temperature below zero. In any case the schedule can be changed according to the need both from the local computer or from a remote one.

The surface conductivity is measured applying, for few cycles, at the probe insulator a power frequency voltage (11 kV) and measuring the leakage current.

The surface conductivity with forced humidification is limited to once per day to reduce the pollutant washing induced by long period of surface condensation on the probe insulator. The pollutant layer requires some time to be totally humidified, depending on the characteristics of the layer itself. AMICO II system determines automatically the minimum necessary time of humidification on the base of the measurements.

Figure 1 shows current, conductivity and its derivative as a function of time.

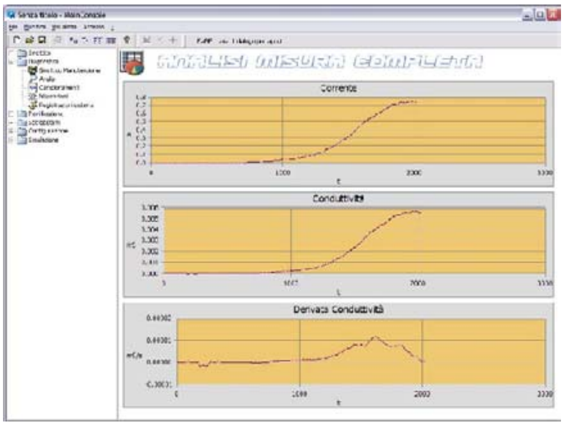

Figure 1: Measured conductivity versus time.

It is shown that the current and conductivity values increase up to a maximum, while the derivative of conductivity after having reached a maximum starts to decrease. It is assumed that the complete humidification of the pollutant layer is reached when the derivative of the conductive reaches a

value equal to 0 during the decreasing phase. At that moment the system heats the liquid to reduce the humidification time of the probe insulator surface.
The conductivity maximum value recorded in each measurement is compared with a limit value and the system automatically generates alarm message in case of higher values. The alarm messages are sent to the remote computer and on request to network operator. In case of lower values, the data are sent once a day to the remote computer.
AMICO II system has 7 main subsystems, and namely:

- Probe insulator. It is of hollow type allowing the circulation of the cooling liquid provoking the condensation of the air moisture on its outer surface (see figure 2)

Figure 2: probe insulator with condensed moisture

Figure 3: Atmospheric condition measuring subsystem

- Subsystem for measuring and recording the atmospheric conditions (see figure 3). In particular, the sensor for the determination of the Dew Point temperature is of cooled mirror type (uncertainty on the Dew Point temperature of the order of 0,2 ºC)
- Subsystem for cooling the insulating liquid circulating in the probe insulator
- Step up transformer (0,22/11 kV – 10 kVA) used to energise the probe insulator for the time necessary to measure leakage current
- Voltage and leakage current measuring subsystem. The system calculates the surface conductivity of the probe insulator from voltage and current measurement.
- Supervisor program. The program controls the complete system: planning of the different operations, recording of the measurement, diagnostic and communication with remote computer.
- Communication subsystem based on GSM protocol. This subsystem allows two ways communication between the local and remote computers.

INSTALLATION OF THE SYSTEM

In total 7 units of the AMICO II system have been assembled, six have been located in six different sites in Italy while one is still present in CESI RICERCA and it is used as development unit.
The six units were installed in six substations of TERNA (Italian TSO) chosen among those having a very high pollution level, as shown in figure 4 reporting the pollution map of the Country derived in the 90's.
The figure shows that the pollution severity of the selected sites is ranked 3 and 4 in scale from 1 to 5 being 5 the most severe. The six units, installed between May and August 2005, are in still in service.
The units were positioned close to the insulators to be monitored paying attention to avoid any protection from rain and wind.

RESULTS

The conductivity recorded during the forced humidification phase has been analysed for each site. The analysis has shown that two sites have practically no salt pollution, in fact the measured value are very close to the resolution of the system. If this could be expected for the site very close to Milan where only industrial pollution is present, it is unexpected for the site in Tuscany characterised by sea wind and that was ranked level 4 (out of 5) in the pollution map of figure 4. Other 2 sites present pollution level slightly higher than measuring resolution. A fifth site, in Sicily, presents medium value of pollution, finally the last site (in Sardinia) presents a very high pollution level as stated by the pollution map of figure 4.

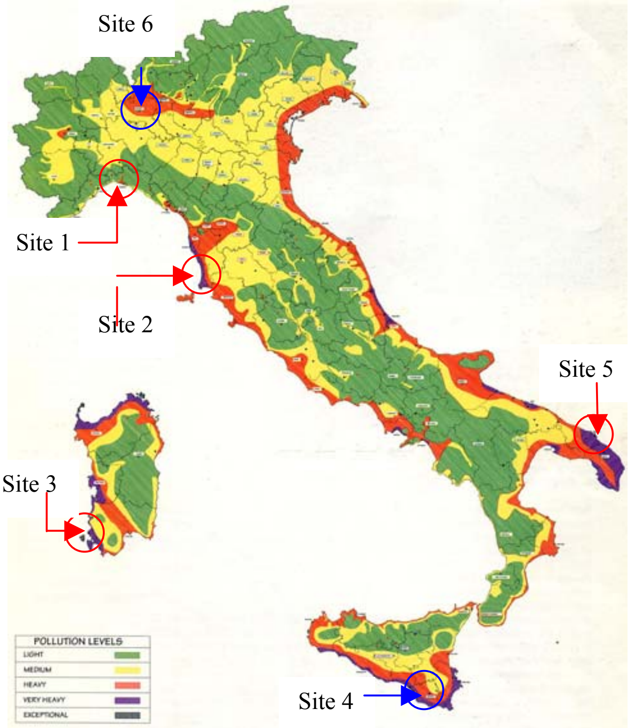

Figure 4: Sites of installation of the 6 units of AMICO II

In figures 5 and 6 the results of Sardinia and Sicily sites are reported for example, the graphs refer to November 2006. Moreover, the two figures report the alarm level, set for the moment at 5 μS.

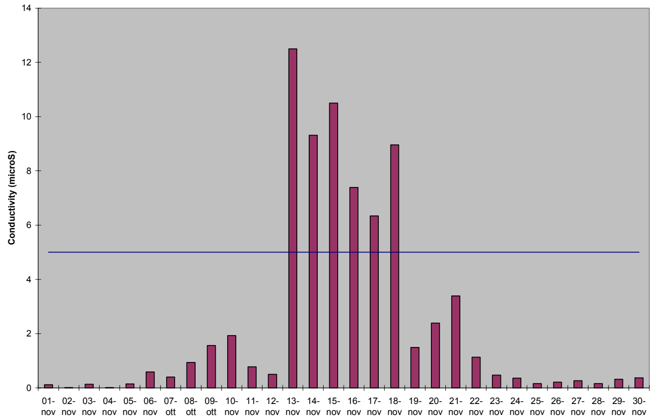

Figure 5: Conductivity of Sardinia site in November 2006

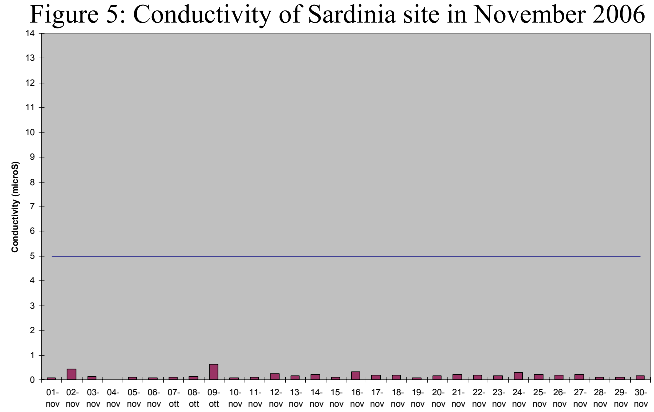

Figure 6: Conductivity of Sicily site in November 2006

RETURN OF EXPERIENCE

The long trial period, more than 18 months, has allowed to solve the most important problems arisen. Two subsystems were the cause of more than 60% of the maintenance operations, and namely the electronic circuit controlling the temperature of the cooling liquid and the determination of the Dew Point temperature subsystem. The non perfect protection against disturbances of electronic circuit controlling the cooling of the liquid was responsible of about 25% of the maintenance; after the improvement this circuit has not suffered other misoperation. The Dew Point temperature subsystem was the cause of about 40% of the misoperations, all the problems were solved changing the assembling position of the cooled mirror and improving the protection against atmospheric stresses. After the implementation no more misoperations were experienced even if the cooled mirror of the sensor requires to be cleaned every few months.

DISCUSSION OF THE RESULTS

The results obtained have highlighted mainly two aspects, and namely:

- The pollution level measured in 5 sites out of 6 are much lower than those reported in pollution map of figure 4
- The alarm limit, set at 5 μS, seems to be very conservative. In fact, in Sardinia site, even with conductivity much higher of the limit (up to 6 times) no pre-discharge phenomena were noticed.

To have a better confidence on the measured conductivity, post insulators used typically in substation were located very close to AMICO II systems, as reported in figure 7 reporting a view of the final lay out. The post insulators are submitted to the same atmospheric conditions of the probe insulator and consequently polluted in the same manner. ESDD of the part of insulator comprised between 2 sheds was measured every month. The sheds considered for the measurements are shifted upward every month. This procedure allows to measure the ESDD value of the same portion of the insulator every year having the selected insulators 24 sheds.

Figure 7: View of the post insulator used for the determination of ESDD

The results of ESDD measurement have confirmed those given by AMICO II systems, as shown in figure 8, where ESDD values measured in Sardinia (blue line) are significantly higher than those measured in Sicily (purple) and Tuscany (sky-blue), the strong decrease of Sardinia ESSD value measured in September is explained by some rainy days before the measurement of ESDD.

For a better definition of the alarm value to be used on site the results obtained in laboratory were compared with those on site. Figure 9 reports conductivity values as a function of ESDD; for on site measurements (Sardinia: blue, Tuscany: sky-blue and Sicily: purple) the values of conductivity and ESDD measured on the same day were reported. The figure shows that for the same quantity of pollutant (ESDD) the conductivity is higher for laboratory tests (orange line and dots) and that the dispersion of on site measurement is much higher than that of laboratory tests. Laboratory tests were carried out according to IEC Standard 60507 requiring to spray uniformly the pollutant on the insulator surface, on the contrary, on site, the distribution of pollutant on the insulator surface is determined by the local environmental conditions. The different pollutant accumulation process can explain the difference evidenced between lab and on site results and stresses the need to continue the research for a better definition of the alarm limit.

CONCLUSIONS

Seven units of AMICO II system were assembled and installed in six different TERNA substations between May and August 2005.
The trial period has allowed to solve the misoperations typical of starting period.
The possibility offered by the design of the system to have a two ways communication between the local and a remote PC was very important not only to transmit automatically the recorded data and possible alarm messages but also to have a complete control of the system itself by a remote computer. The GSM protocol used at purpose has guaranteed a very large flexibility and independence of the local lay out of the substation but at the same time the information exchange rate was slow and long time is required in case of upgrading of the control program.
Finally, the results obtained up to now have shown the need to continue the research on site and in laboratory to get a better definition of the alert value, and a possible variation of the Italian pollution map derived in the 90's by ENEL Distribuzione; this variation shall be confirmed by the results of the next year.

ACKNOWLEDGENT

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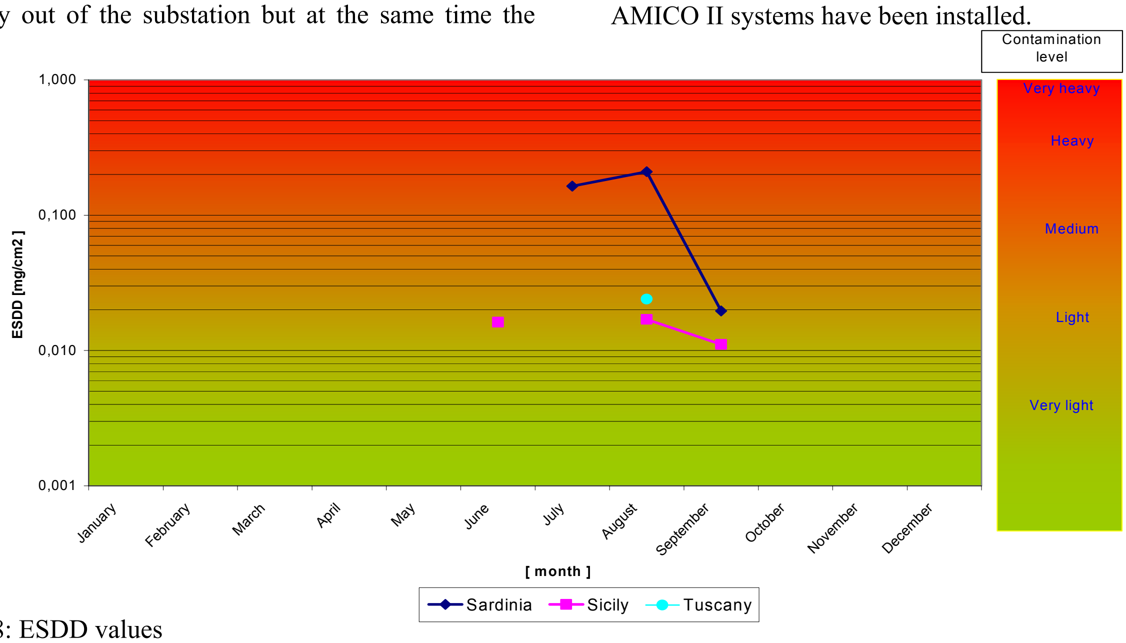

Figure 8: ESDD values

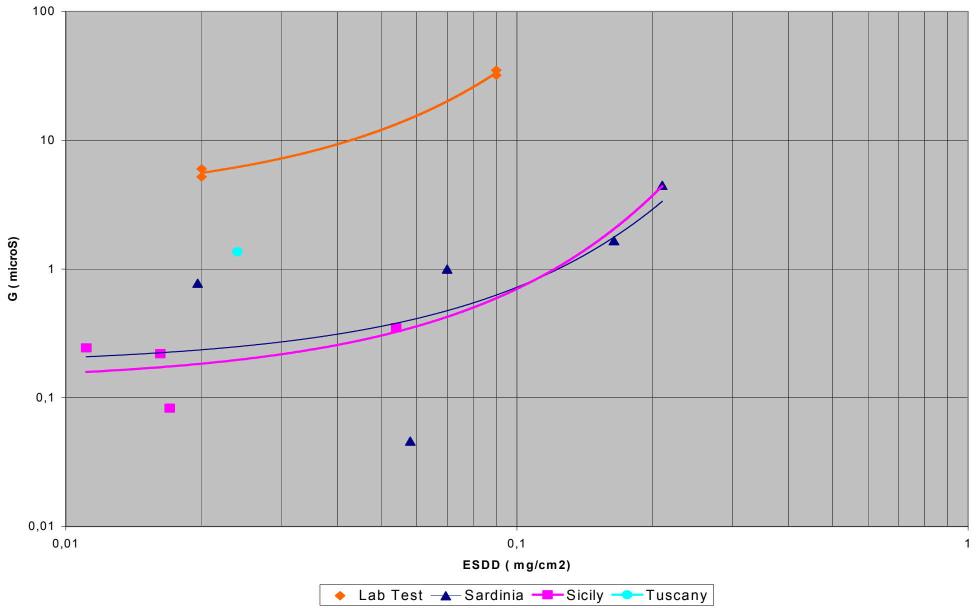

Figure 9: Conductivity as a function of ESDD.