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SECTOR A - Paper A13

**20 years working in electronics for Cathodic Protection: in-field  
experience and future innovation**

**20 ans d'activités dans l'électronique pour la protection cathodique:  
expérience en la matière et innovations futures**

**20 Jahre Arbeit für die Elektronik beim kathodischen  
Korrosionsschutz: Feld-Erfahrung und zukünftige Neuerungen**

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## **Abstract**

Since 1985 Epsilon has been engaged in the field of cathodic protection. Our equipments are widely used (thousands of pieces) in Italy and in North Africa, mainly by SNAM, SNAMPROGETTI (ENI group) with very good results in terms of performance, simplicity of use and reliability.

Epsilon production is devoted to electronic equipments and software packages such as:

- Automatic Cathodic Protection power supply with Remote Control features;
- Cathodic protection monitoring/storing microprocessor instruments;
- Wireless Remote Data Acquisition equipment based on GSM/GPRS connection;
- Software package for cathodic protection data management.

Feedback from various in-field experience collected during these years of activities will be shown and discussed.

In the last years the new software and hardware technologies allow to design more advanced solutions in the field of cathodic protection. Epsilon is directly involved in the development of these new technologies. The paper will relate about the most promising aspects of them.

## **Résumé**

Epsilon est active dans le domaine de la protection cathodique depuis 1985. Notre matériel est largement utilisé (des milliers de pièces) en Italie et en Afrique du Nord, principalement chez SNAM, SNAMPROGETTI (groupe ENI), enregistrant d'excellents résultats en termes de performance, de simplicité d'emploi et de fiabilité.

La production d'Epsilon se concentre sur les équipements électroniques et les progiciels tels que:

- Alimentateurs automatiques pour protection cathodique avec dispositif de commande à distance;
- Instruments à microprocesseur d'enregistrement/ de contrôle de protection cathodique;
- Dispositif d'acquisition de données sans fil par le biais d'une connexion GSM/GPRS;
- Progiciel de gestion des données de protection cathodique.

Un compte-rendu de diverses expériences en la matière, rassemblées pendant ces nombreuses années d'activité, sera présenté et fera l'objet d'une discussion.

Ces dernières années, les nouvelles technologies sur le plan du matériel et des logiciels permettent de concevoir des solutions plus perfectionnées en matière de protection cathodique. Epsilon est directement impliquée dans le développement de ces nouvelles technologies. Le document en abordera les aspects les plus prometteurs.

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## 1. Introduction

The explaining we wish to show is a little bit out of ordinary. Normally the producer of an equipment put the emphasis on the good result and the positive features of his own products. On the contrary we put our effort to present you the causes of faults happened in the last years on our cathodic protection electronic equipment.

We think that an accurate fault analysis is necessary to plan an equipment development and to assure an high quality level.

The documentable very high MTBF of our products allow us to show the in-field problems we checked without compromising our excellent reference on the market.

## 2. The philosophy: software instead of hardware.

Epsilon is specialized in the design and the production of hardware and software for special purpose electronic equipment.

Since 1985 we have been engaging in the specific field of cathodic protection field. Our equipment are widely used (thousands of pieces) in Italy and North Africa by SNAM Rete Gas, SNAMPROGETTI and SAIPEM (ENI group) with very good results in terms of performance, simplicity of use and reliability.

Our production regards the electronic equipment and software tools needed for the cathodic protection and its monitoring and remote control. The know-how ripened in many years of activity allows us to design and supervise the installation of the cathodic protection systems and monitoring their operating conditions on pipelines, tanks or other plants.

All Epsilon instruments are realized using new electronic techniques as microprocessors and DSP (Digital Signal Processor), analog to digital conversion, power switching techniques etc. and, in the years, we constantly work to design new solutions. The most important idea that guides us is to apply, every time it is possible, a software algorithm instead of hardware circuits; so our equipment are software based. The results due to the use of this philosophy are the following:

- **Reliability:**

The software is unfailing! If we find some “bugs” we will always adjust them.

- **Stability:**

All the digitalized parameters are processed in a numerical way so we can know a priori the final precision. The equipment precision isn't affected by temperature, voltage or other physical parameters.

- **Remote control:**

We propose a full remote controllable cathodic protection system via GSM/GPRS/UMTS network. The operations of the control centre, towards the equipment in field, are supported by special software package.

- **Diagnostic capability:**

The diagnostic capability of a software-based equipment can help the maintenance technicians involved in the maintenance activities. The in-field experience allows us to improve and to specialize the diagnostic indications.

- **User-friendly interface:**

The cathodic protection power supply equipment are provided with a functional keyboard and an alpha-numeric display with clear indications. These messages are in the language of the customer and simplify the learning of the cathodic power supply operation procedures.

- **Flexibility:**

At any time it is possible to include into the software procedure particular algorithms to realize new features.

Our products are the following:

- cathodic protection power supplies;
- remote control systems
- data logger

### 3. Cathodic Protection power supply equipment



The  $\mu$ PEAL family, from 400W up to 2500W, are a rugged, full microprocessor controlled automatic power supplies, which has been designed for metal structures cathodic protection field (e.g.: oil, methane or water pipeline, chemical plants, tanks, etc.).

At the present time about 3000  $\mu$ PEAL are installed in Italy, north Africa and other countries in Europe. The  $\mu$ PEAL is homologated by “ENI Group” companies.

The MTBF (Mean Time Between Failure), calculated in field, is over the 100.000 hours.

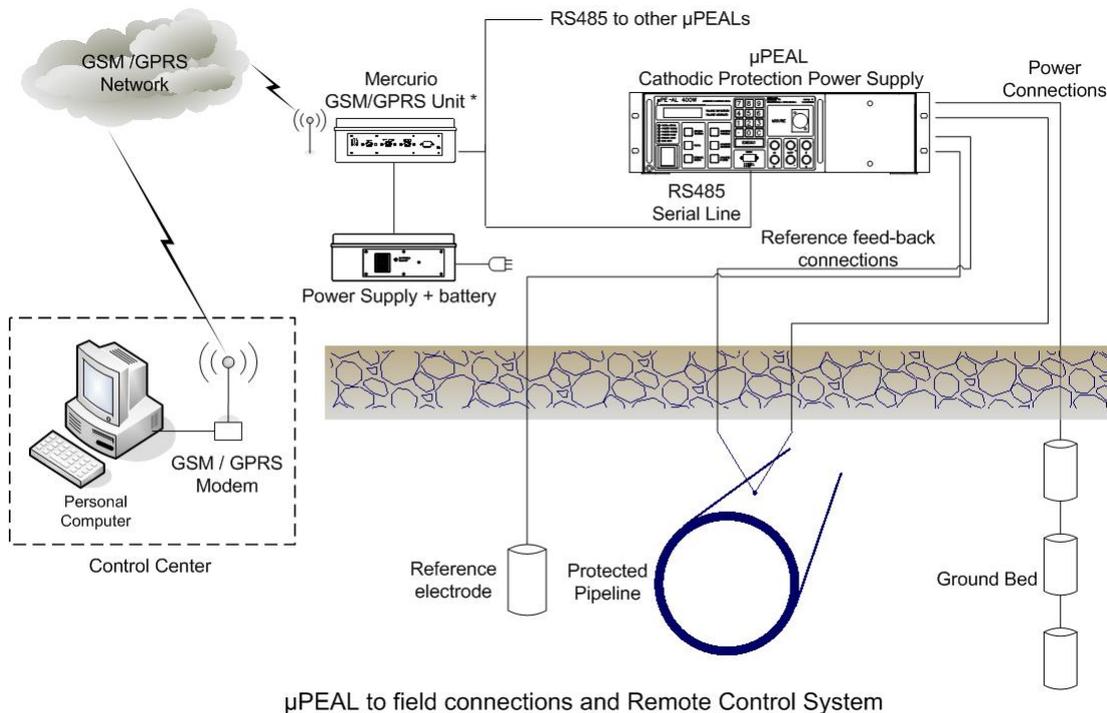
The  $\mu$ PEAL is designed up the date with advanced technological solutions, the output power is regulated by PWM technique, very fast directly controlled by the microprocessor (DSP).

In compliance with UNI EN 12954:2002 and UNI CEI 8:1997,  $\mu$ PEAL family equipment can operate with output power from 400W (8A @ 50V) to 2500W (50A@50V) depending on the model, in the following way:

- CC: Constant Current
- CV: Constant Voltage referred to a reference electrode
- CV+Ib: Constant Voltage with a base (minimum) of current

The output current/voltage is not influenced by a 50÷60 Hz sine wave Vac present between the pipeline and the reference electrode.

It is available a complete control and monitoring remote system based on a RS485 communication network, for the short range distance, and on GSM/GPRS wireless network for the large scale distance. This communication system is well supported by software.



$\mu$ PEAL to field connections and Remote Control System

\* Snam Rete Gas name: AEMT

#### 4. GSM/GPRS remote control system

Epsilon offers a complete hardware & software system for the remote control of the Cathodic Protection, including data transmission through the wireless GSM/GPRS network.

The remote control is fully supported by the software package CP Watch (Cathodic Protection Watch); under Windows 2000/XP, the configuration, the control and the operation of the complete system, as well as its maintenance, are available to the operator.

With the CP Watch package all monitoring and control operations for a virtually infinite network of CP devices are realizable: Mercurio GSM/GPRS Units, CPW Units and  $\mu$ PEAL power supplies.

Two kinds of remote control unit are available:

##### 4.1 Mercurio GSM/GPRS Unit.



This equipment is designed to allow the remote control of one or more cathodic protection power supplies. In addition to this feature the unit can acquire voltage and current measures.

Mercurio GSM/GPRS is homologated by SNAM (ENI Group). It is to be integrated in a control system for Cathodic Protection, in compliance with actual European standards: UNI 10950:2001, UNI 11094:2004 and UNI EN 13509:2004.

Mercurio GSM/GPRS is manufactured since 1990, with periodic technology updates and substantial improvements. As many as 2,800 units are in service in Italy and North Africa, controlling gas pipelines by SNAM Rete Gas S.p.A (ENI Group), with successful results.

The Mean Time Between Failures (MTBF) reported from field is over 200,000 hours.

Mercurio GSM/GPRS includes data conversion (analogue to digital), data processing and storage of field information collected by a Cathodic Protection network (like voltage and current imposed).

At programmable time intervals, Mercurio GSM/GPRS activates the transmission of all stored data, through a GSM/GPRS wireless link, to the network Control Centre.

The unit can be connected, through an isolated serial channel RS485, to one or more  $\mu$ PEAL power supplies.

This means that the field can be supervised remotely from the Control Centre, through the Mercurio GSM/GPRS unit and the GSM/GPRS network.

Mercurio GSM/GPRS can be equipped with up to 4 data acquisition channels, dedicated to electrical parameters of sensitive point of the cathodic protection systems. These analogue channels are all isolated from each other.

Various alerts like: mains voltage supply missing, unauthorized intrusion into the system, faulty power supply for cathodic protection, etc. are immediately notified to the Control Centre through a GSM/GPRS link or through an SMS message.

The transmission protocol through the Mercurio GSM/GPRS and the Control Centre includes specific safety features to prevent any unauthorized access.

#### 4.2 CPW Unit.

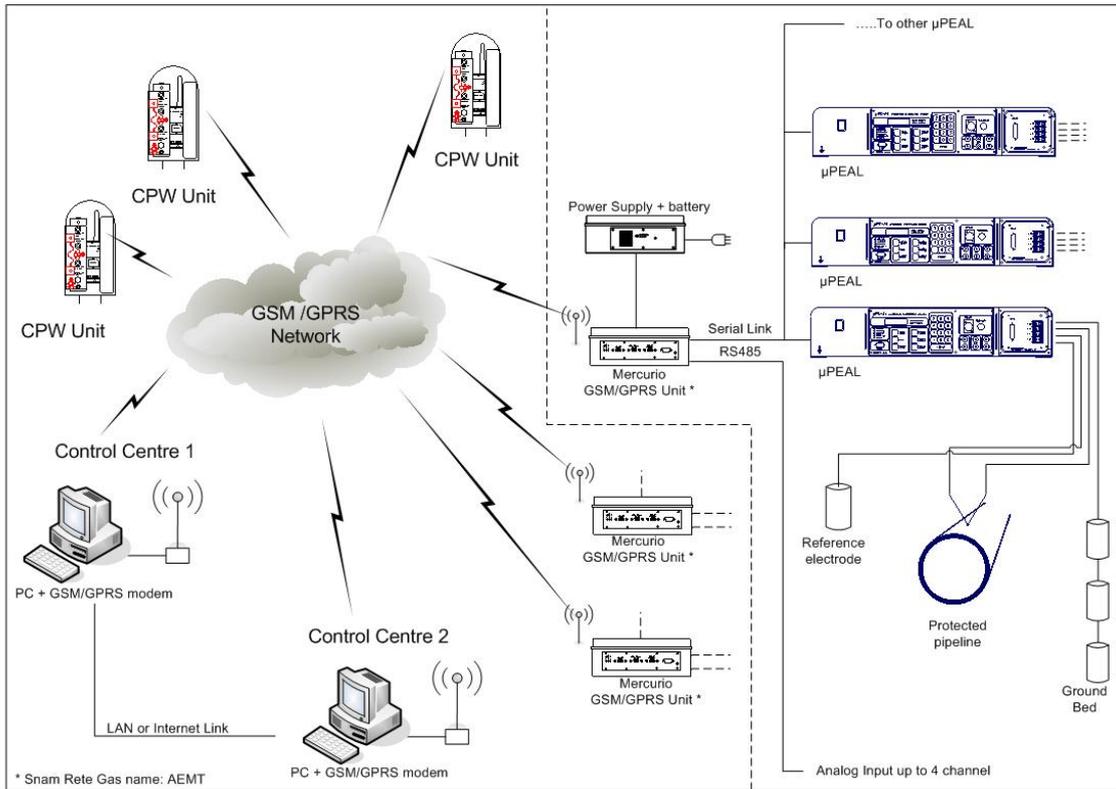


The CPW Unit is a very low power consumption equipment: three 1.5V alkaline size “D” batteries assure three years of operation with a daily GSM connection.

CPW Unit is designed according to SNAM Rete Gas (ENI Group) specifications and it is suitable to realize the cathodic protection monitoring system as required by the European Standard: UNI 10950:2001, UNI 11094:2004 and UNI EN 13509:2004.

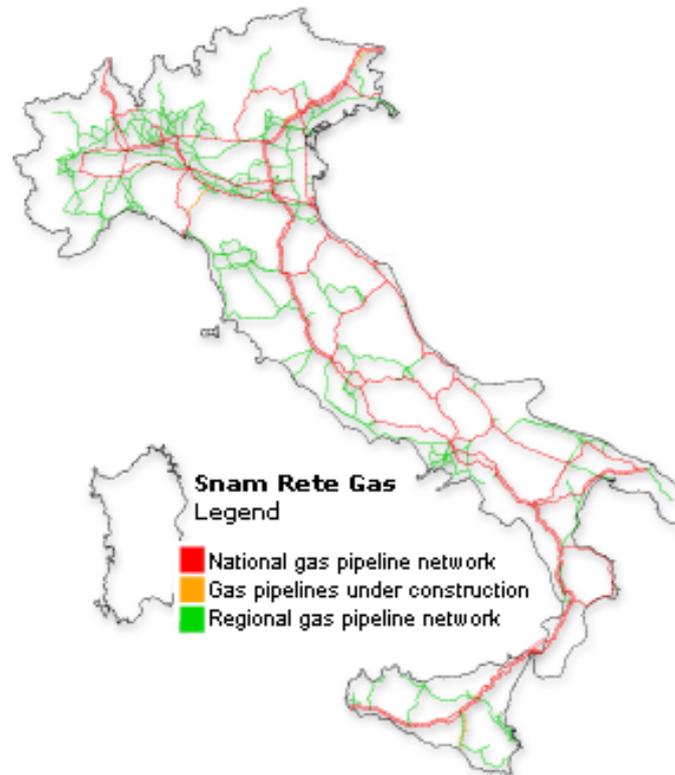
CPW Unit allows the following:

- electrical measurements acquisition (two voltages, or one voltage and one current );
- high precision analogue/digital conversion of the electrical variables detected;
- values processing: filtering, minimum, average, maximum, etc.;
- storage of collected data;
- transmission on GSM/GPRS wireless network of data necessary for cathodic protection monitoring.



Cathodic protection system with remote control.

## 5. SNAM Rete Gas natural gas pipeline system



The picture shows the Snam Rete Gas transmission system that consists of approximately 30,545 Km of natural gas pipeline with a diameter from 20 to 1200 mm and a pressure between 0.5 and 75 bar. The network includes eleven compression plant (source: [www.snamretegas.it](http://www.snamretegas.it)).

## 6. Cathodic Protection equipment reliability and fault analysis

For many years we stored data of all the faults happened in field on our cathodic protection equipment. Most of these equipment are installed on the SNAM Rete Gas pipeline network.

All Epsilon equipment are repaired exclusively in our laboratory so we are sure to check the full number of fault ones.

In the following a subdivision of types of faults as been made in order to highlight a complete fault analysis.

We have divided the faults into three groups depending on the main cause that prime the fault process. Sometime the prime cause is easily noticeable, in other cases we can only suppose the origin of the fault.

The fault groups are the following:

- electronic faults:
  - power electronics faults
  - analogical electronic faults
  - control electronic faults
  - GSM equipment faults
- Over-voltage faults:
  - lightning
  - power line over-voltage
- Environmental faults:
  - insects and little animals
  - floods and hurricane
  - thefts and car accidents

In the following paragraphs we will examine the different kinds of faults happened during last years. This analysis is a qualitative one, the relevant quantitative one is shown in paragraph 7 and 8.

### **6.1. Power electronics faults**

In this category we put all the faults occurring on the power component that realize the power circuits of the  $\mu$ PEAL power supply equipment.

No GSM remote control equipment are listed in this category because the power circuits aren't in these ones.

The power circuits generate heat that is dissipated outside the equipment box in the air. It is normally accepted the relation: more circuit heat  $\rightarrow$  less circuit life. To reduce the power electronic temperature we can operate in two directions:

- reduce the power loss of the power circuits.

Today we can use a wide range of high efficiency electronic power components, as Power MOSFET and IGBT transistors. The performance of these components is constantly improved as power losses and switching time.

In the last ten years the use of these components allow to design and to realize high frequency switching converter with high efficiency, that means less heat. These

techniques have permitted a big decrease in the power circuits dimension, in particular for the dimension of the transformer and in general for the magnetic part.

With the use of very high speed microprocessors, as DSP (Digital Signal Processor), for the control of the power circuits we realized fast and well controlled power electronic and consequently we improve the equipment reliability.

- improve the facility to dissipate the heat from the electronic components to the air.

We introduce in our power circuits the use of a special kind of copper or aluminum printed boards instead of the classic fiberglass substrate printed boards. This technology allows to reduce drastically the heat resistance from the electronic component core to the cooler. Moreover the automatic mounting technique of these boards permits to assure a very high and stable quality.

## **6.2 Analogical electronics faults**

These parts of the electronics operate with very low level signals in a very high impedance circuits. This situation can become critical if some external conditions as temperature, humidity, dirt on the circuit etc. cause a drift from the design operating condition.

To reduce the incidence of these problems we think that the better solution is to entrust these functions to the software algorithms everywhere it is possible.

## **6.3 Control electronics faults**

The reliability of this electronics is very high above all, considering the complexity of components as the microprocessors. The low number of this kind of faults is mainly due to problems in the mounting procedure.

## **6.4 GSM equipment faults**

The incidence of this kind of faults is very low.

Over 25,000 pieces of equipment with GSM feature, not only used in cathodic protection field, is the yearly Epsilon production; the GSM engines faults rate of is about 0,25%. Practically all these faults are discovered during equipment final test procedure.

Some problems are due to the SIM card. We rarely observed some irritating SIM card intermittent problems.

## 6.5 Power supply batteries and back-up batteries faults

The cathodic protection equipment are located near the pipeline in open field. High or low temperature, humidity, salinity etc. are the environmental conditions depending on the locations. In these conditions the batteries are very critical component.

We can individuate three different kinds of battery functions:

- the little Ni-Cd or Lithium battery, mounted on printed circuit board, to back-up the RAM memory needed to retain the stored data and the setup data. The new design products use other techniques to realize these features. EEPROM or Flash Memory can be used to store data without power supply to preserve it.
- the power supply batteries needed in self powered equipment like CPW Unit. Where the installation place is not fitted out with power line it is mandatory to use batteries.

The choice of the power supply batteries requires great attention:

- for low energy requirement: alkaline battery (easy to find, cheap, very rugged, wide temperature range, not rechargeable) or lithium ion battery (high energy/volume rate, wide temperature range, expensive, normally not rechargeable).
- for high energy requirement: acid lead battery. This kind of batteries needs a recharge system that, today, normally is a photovoltaic solar panel.
- the back-up batteries needed to assure some functions, as the transmission of an alarm SMS message, when the main power supply goes down.

We prefer to recommend our customers not to use batteries in this kind of equipment if it isn't strictly needed. Otherwise it is possible to equip sealed acid lead batteries, normally under recharge, to allow short time of equipment activity, without the main power. It is important that this ON time is limited and after the equipment must go automatically in OFF state to avoid a total discharge of the battery.

Anyway the batteries are less reliable than the other components and they represent a critical point of the cathodic protection equipment reliability mostly when these equipment are called to work for long time in critical environmental conditions.

## 6.6 Lightning

The pipeline is realized in steel so it is a good conductor of electricity. The high voltage generated by a lightning discharging near the pipe affects all the pipeline.

The cathodic protection equipment are connected with the pipeline so the over voltage generated by lightning arrives to these instruments. We can identify two kinds of connection:

- measure connections. Both power supply and control equipment normally perform measures using analogical channel in high impedance (from 500k $\Omega$  to 2M $\Omega$ ). This high impedance allows to design a special circuit that limits the over-voltage to a reasonable value with a dissipation of few energy.

The faults incidence in this kind of circuit is low.

- power connections. To supply the cathodic protection voltage level to the pipeline the power supply equipment needs a low impedance connection with the pipeline and the ground bed (anode). We protect these connection with very big dischargers to limit the voltage to few hundred volts. These components are able to absorb up to 50kA (8/20  $\mu$ S test discharge). The maximum energy dissipated is 450 Joule. So we have the following effects:
  - The dischargers absorb the lightning energy, there is no fault.
  - The dischargers are damaged by the high lightning energy but all other electronics are preserved. In Epsilon equipment it is very easy, in field feasible, to change the over-voltage protection block.
  - The lightning energy was so high that all the power supply equipment are involved in the discharge. Sometimes all the field cabinet is destroyed.

In many years of activity we tested a variety of different solutions and today we propose a good feature/expense one.

We note that there is big variability in the lightning discharge frequency in the different geographic locations. In Italy the most critical zones are the Alps and the Apennines in spring and summer and some zones in the South of Italy (Sicily and Calabria) in the winter.

The lightning activity is variable in the years; in the last 5 year the meteorological service refers a lightning increment of about 30% than in the precedent 5 years.

## **6.7 Main power line over-voltage**

The over-voltage on the main power line often can be due to a lightning discharged on the main line. Sometime a big and fast variation on the main line load or a switch on/off of an big inductive load can cause the over-voltage.

The equipment that are powered by the main line are protected in the following way:

- with a main line filter to prevent the faults or the restart of the electronics control circuit;
- with varistors to limit the voltage at main line input.

Normally these protections are sufficient to avoid damage when the energy of the over-voltage phenomena is not very high. In some locations, where the problem often repeats itself, it is possible to install an additional protection.

## **6.8 Insects and other little animals**

The cathodic protection equipment are located near the pipeline often in open country-side. The box of these instruments can become a warm and comfortable nest for a lot of different kinds of insects and little animals.

The power supply equipment are more subject to these problems because they are warm. Moreover the boxes of this equipment are provided with slits to allow heat dissipation.

We found inside our equipment insects as: ants, wasps, bees and little animals as little mice, snakes, geckos and lizards. We note that the equipment normally works correctly for a long time, also with these guests, but the electronics circuits are, in the time, destroyed by the defecations. This happened more often with the ants and the mice. Sometimes the mice realize their nest over the power supply equipment with the same effect delayed in the time.

The choice of the equipment location is essential to prevent these faults.

## **6.9 Floods, landslide and hurricanes**

Floods, landslide and hurricanes are responsible of some equipment destruction. Normally the instruments are not reparable.

It is easy to understand that a good choice of the equipment location could avoid some of these faults.

## **6.10 Thefts and car accidents**

The incidence of the thefts is not negligible if the plants are equipped with something that are visible. In particular the photovoltaic solar panel are often stolen.

Normally the GSM/GPRS antennas are located inside the instrument box but if the level of the GSM field is low it is possible to equip outside an antenna with a high gain. This antenna indicates to the thefts the presence of something to steal. To minimize this problem we realized a kind of antenna that appear as a pole.

If the pipeline plant isn't good accepted by the local population some damages are possible and the cathodic protection equipment are very vulnerable.

The car accidents occur when the equipment are located near a road but also near a parking area. Sometimes the farm equipment are responsible of the damage.

The increase of the number of the GSM remote control equipment, like CPW Units, installed in field causes the increase of incidence of the car accidents faults.

Normally this kind of accidents destroy the equipment that after cannot be repaired.

The choice of the equipment location is very important to limit this kind of faults. Sometime, like in the parking zone, it is sufficient to put a protection around the equipment cabinet.

## 7. MTBF (Mean Time Between Failure) computation

The MTBF is calculated with the following formula:

$$\text{MTBF} = (\sum_{i=1}^n \langle \text{operation time of equipment } i \rangle) / \langle \text{total number of faults} \rangle$$

where n is the number of the equipment put in the computation.

The result of the formula is a time, normally hours.

We show the data related to the cathodic power supply  $\mu$ PEAL and to the Mercurio GSM/GPRS remote control equipment.

- **$\mu$ PEAL MTBF computation**

Since 1999 Epsilon delivered the first automatic power supply with remote control named  $\mu$ PEAL and we started to store the data related to the maintenance operations.

From 1999 to 2005 we collected 80.7 millions of operation hours with a total of 662 faults: the MTBF is 121'957 hours.

- **Mercurio GSM/GPRS Unit MTBF computation**

Starting at the end of 1999 we stored the data related to this equipment.

From 1999 to 2005 we collected 100.5 millions of operation hours with a total of 448 faults: the MTBF is 224'238 hours.

The MTBF calculated for the  $\mu$ PEAL power supply equipment is very high compared with the MTBF declared for other power supply equipment with the same characteristics.

The MTBF of the Mercurio GSM/GPRS Unit is approximately double of the  $\mu$ PEAL one; it depends on the different kind of equipment. The incidence of the different faults is shown in the next paragraph.

The result of the calculation delineates a good reliability for both the equipment. Moreover in the years the equipment become ever older, some instruments are working since six years, but we don't observe an increment of faults rate.

For the CPW Unit we don't have a sufficient quantity of data to calculate the MTBF statistics because this equipment is in field only from the beginning of 2005. The analysis of the first data and some considerations allow to attempt a MTBF higher than the Mercurio GSM/GPRS Unit one.

## 8. Faults quantitative analysis

The data we show here below

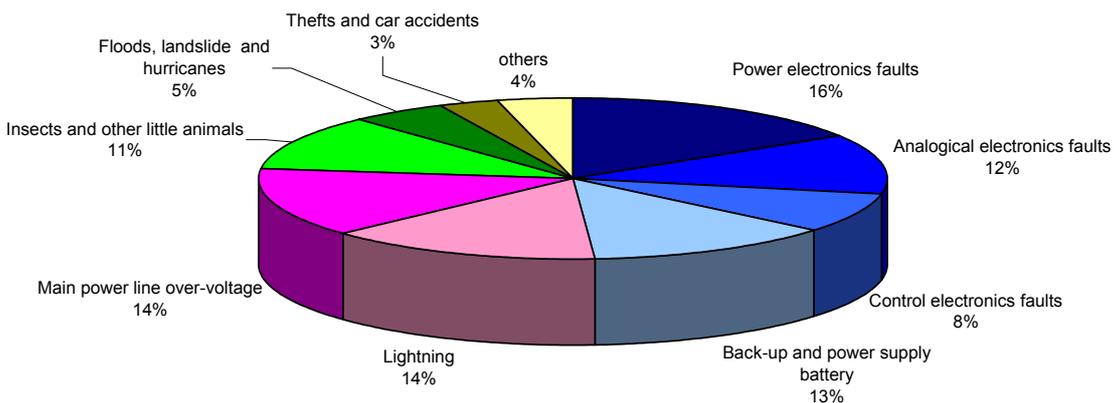
is related to the cathodic power supply  $\mu$ PEAL equipment and to the Mercurio GSM/GPRS remote control Unit. To analyze these data we must remember that the fault rate of  $\mu$ PEAL is about double respect to the fault rate of Mercurio GSM/GPRS Unit.

Due to the difference on the typology of faults between the two equipment it becomes difficult to compare the rates of the two graphics.

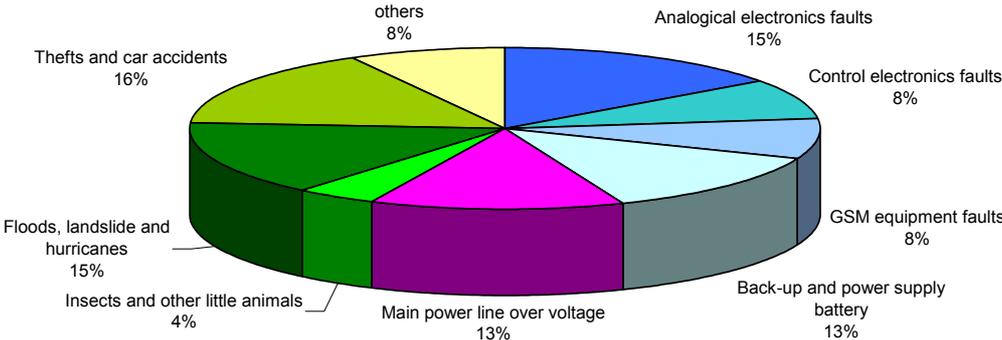
Referring to the graphics:

- the blue tonality shows the rates depending on electronics faults that are about the half of the total faults.
- the violet tonality shows the rate of lightning and over-voltage faults. This kind of faults are more relevant for  $\mu$ PEAL as we explained in paragraph 6.6.
- the green tonality shows the environmental faults. The incidence of this faults is more important for Mercurio GSM/GPRS Unit than for  $\mu$ PEAL because it can be located in less safety place. Anyway this difference isn't so big if related to the number of faults.

**$\mu$ PEAL cathodic protection power supply equipment faults split**



### MERCURIO GSM/GPRS remote control equipment faults split



### 9. Conclusions

The data showed in this paper normally are company very reserved information! The very good reliability performance allow Epsilon to publish these results.

The analysis that Epsilon presents in this paper would be a little contribute to the knowledge in the cathodic protection reliability. It can be an help to calculate the maintenance costs of a cathodic protection system with GSM/GPRS remote control.

We will be happy to give more information and technical support to everybody is engaged in cathodic protection.