SECTOR A

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Novel multiple CP feeders for the Cathodic Protection of Complex Structures by using distributed groundbeds

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Abstract
In many industrial applications the use of distributed groundbeds is to be considered either very useful or unavoidable. This is typically the case of Complex Structures, where impressed current cathodic protection systems are generally used, and several configurations of groundbed may be considered (remote or close groundbeds: single point, distributed or continuous groundbeds).
The use of multiple groundbeds is therefore to be envisaged for Compressor or Pumping Stations, Gas or Oil distribution systems, large Reinforced Concrete Structures, buried and mounded Tanks.
Whenever many different groundbeds are used, it is highly recommended the use multiple CPPS (Cathodic Protection Power Supply), since they allow an accurate and local control of currents and potentials, thus allowing a careful distribution of the C.P. Current and avoiding excessive polarisation of the steel cathodically protected. This paper describes the capabilities of a multiple power supply especially designed for cathodic protection application: the MODU-PEAL.
MODU-PEAL can be equipped with a maximum of 12 independent power supply modules, each one isolated from the others. Each power supply module can deliver continuously up to 200W (4A@50V).

Each module can be set at the typical operation modes of modern impressed current cathodic protection power supplies:

- Constant Current Mode (CCM):

  each module keeps constant the current that flows between the ground bed and the structure to be protected. The precision of regulation is very high and the errors are less than ±4mA up to 1A and ±40mA in the range 1A÷4A;

- Constant Potential mode (CPM):

  the potential difference applied between the reference electrode and the structure is kept constant.
  In this case too, the precision is high: ±30mV in the range -1V ÷ -5V;

- Base Current Mode (CPM+Ib):

  the Potential measured between the reference electrode and the structure is kept constant, similarly to the CPM mode, but a minimum Base Current (Ib) between the ground bed and the structure is always assured.

MODU-PEAL has been conceived so that it is completely and remotely controlled either by a serial isolated connection (RS485 channel) or by wireless devices (Mercurio GSM/GPRS unit).

The remote control is supported by the software CP Watch (Cathodic Protection Watch), that allows to control all the cathodic protection devices produced by Epsilon, using the wireless technology.

1 - Introduction

In many industrial applications the use of distributed groundbeds is to be considered either very useful or unavoidable. This is typically the case of Complex Structures where impressed current cathodic protection systems are generally used, and several configurations of groundbed may be considered (remote or close groundbeds: single point, distributed or continuous groundbeds).
According to the EN Standard 14505, a ***"Complex Structure"*** is defined in the following way: *"structure composed of a structure to be protected and of one or more foreign electrodes which, for safety or technical reasons, cannot be electrically separated from it."*

Impressed current cathodic protection systems are generally used in complex structure applications.

Depending on the method chosen, several configurations of groundbed may be considered (remote or close groundbeds: single point, distributed or continuous groundbeds). When designing a groundbed system, it is always important to consider the following points:

- groundbed lifetime;
- groundbed locations are to be selected in such a way that inadmissible interference to foreign structures and shielding effects are avoided (ref. Standard - EN 50162 : 2004);
- the groundbed resistance to earth should be kept as low as possible;
- it should be possible to control the currents of individual anodes and groundbeds;

The Standard, in order to be more general, does not give detailed indication on the distribution of the anode beds within this kind of Structures. Typical cases of use of multiple CPPS (Cathodic Protection Power Supply) can be the following:

- Compressor or Pumping Stations;
- Gas or Oil distribution systems;
- Gas or oil networks collectors;
- Mounded vessels
- Others

If the corrosion world of structures other than pipelines and relevant accessories is considered, the use of distributed CPPS (Cathodic Protection Power Supply) is particularly suited for the CP of reinforcement steel of typical industrial structures such as Cooling Towers, river or sea banks, reinforced concrete of foundations and many others.
Whenever the use of multiple groundbeds is to be envisaged, it is highly recommended the use of multiple CPPS (Cathodic Protection Power Supply); they allow an accurate and local control of currents and potentials, thus avoiding excessive polarisation of the steel cathodically protected.
Useful indication of this kind of installation (distributed anode groundbeds) are also given in the EN 13636 - June03 - CP of buried Tanks and related piping: Groundbeds "*Tanks originally constructed above ground and subsequently covered with a layer of earth will require anodes to be distributed to achieve full cathodic protection for all soil conditions*."

2 - The modular CP feeder MODU-PEAL

MODU-PEAL can be equipped a maximum of 12 independent power supply modules, each one isolated from the others. Every power supply module can deliver continuously up to 200W (4A@50V).
Each module can be set at the typical operation modes of modern impressed current cathodic protection power supplies:

- Constant Current Mode (CCM):

  each module keeps constant the current that flows between the ground bed and the structure to be protected. The precision of regulation is very high and the errors are less than ±4mA up to 1A and ±40mA in the range 1A÷4A;

- Constant Potential mode (CPM):

  the potential difference applied between the reference electrode and the structure is kept constant.
  In this case too, the precision is high: ±30mV in the range -1V ÷ -5V;

- Base Current Mode (CPM+Ib):

the Potential measured between the reference electrode and the structure is kept constant, similarly to the CPM mode, but a minimum Base Current (Ib) between the ground bed and the structure is always assured.

MODU-PEAL is equipped with the following functionality used to check the operating conditions:

- **Automatic Test**: this procedure allows to verify the good connection of the MODU_PEAL to the structure and the ground bed, checking the current that flows through them.
- **Internal Cyclic Switch**: allows to activate the ON/OFF operating mode at preset ON/OFF intervals time.
- **External Cyclic Switch**: the equipment can be connected to an external trigger signal to operate the ON/OFF procedure synchronized to this signal.
- MODU-PEAL can be electrically connected or disconnected to the ground bed-structure line, by a keyboard command, without physically detach the cables.

The MODU-PEAL has been designed and developed on the basis of the most recent switching regulation techniques, which allow to obtain very good efficiencies. A powerful DSP (Digital Signal Processor) controls all the output quantities and the regulation parameters. It also controls a keyboard and a display by which it is easy to set the current and the voltage regulation levels and to display the correspondent measured values.

The voltage/current regulation and the feedback process are totally realized in numeric form by a specific software (firmware) loaded in the processor (DSP) memory Unit. This guarantees a very high regulation stability in all the environmental condition and during time.

MODU-PEAL is immune to typical electrical noises (50Hz) induced in the structure by electrical engines, couplings, leakages, and can also regulate a possible positive protection current eventually existing between the ground bed and the structure.

Its input and output are equipped with specific and strong protection circuits to prevent overvoltages due to lightnings.

Like all the cathodic protection power supplies designed and manufactured by Epsilon, MODU-PEAL is completely remotely controlled by a serial isolated connection (RS485 channel) or by wireless devices Mercurio GSM/GPRS unit, as schematically shown in Figure 1.

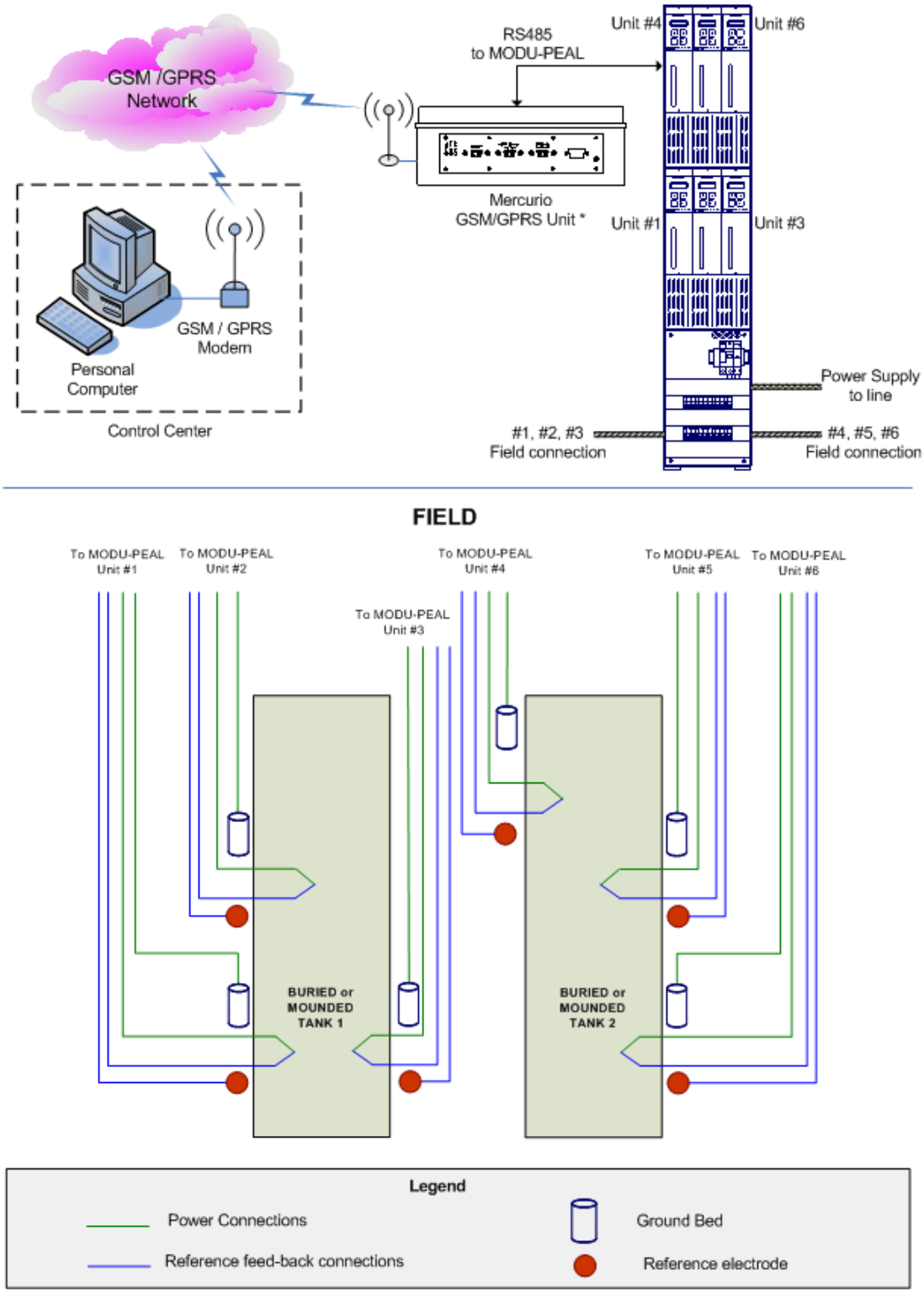


Figure 1 – MODU-PEAL schematic connections to the field and to the wireless remote control system

The remote control is supported by a software named CPW (Cathodic Protection Watch), that allows to control all the cathodic protection devices by Epsilon, using the wireless technology.

The MODU-PEAL mechanical size is very small; a completely equipped one (12 power supply units) is shown in Figure 2 where the dimensions are indicated. It is possible to install the MODU-PEAL in a cabin without any other mechanical protection, or it is easy to install the equipment in a water-proof of fire-proof cabinet for in field installation.

A series of screw connectors placed in the lower section of MODU-PEAL allows directly the field cables connection.

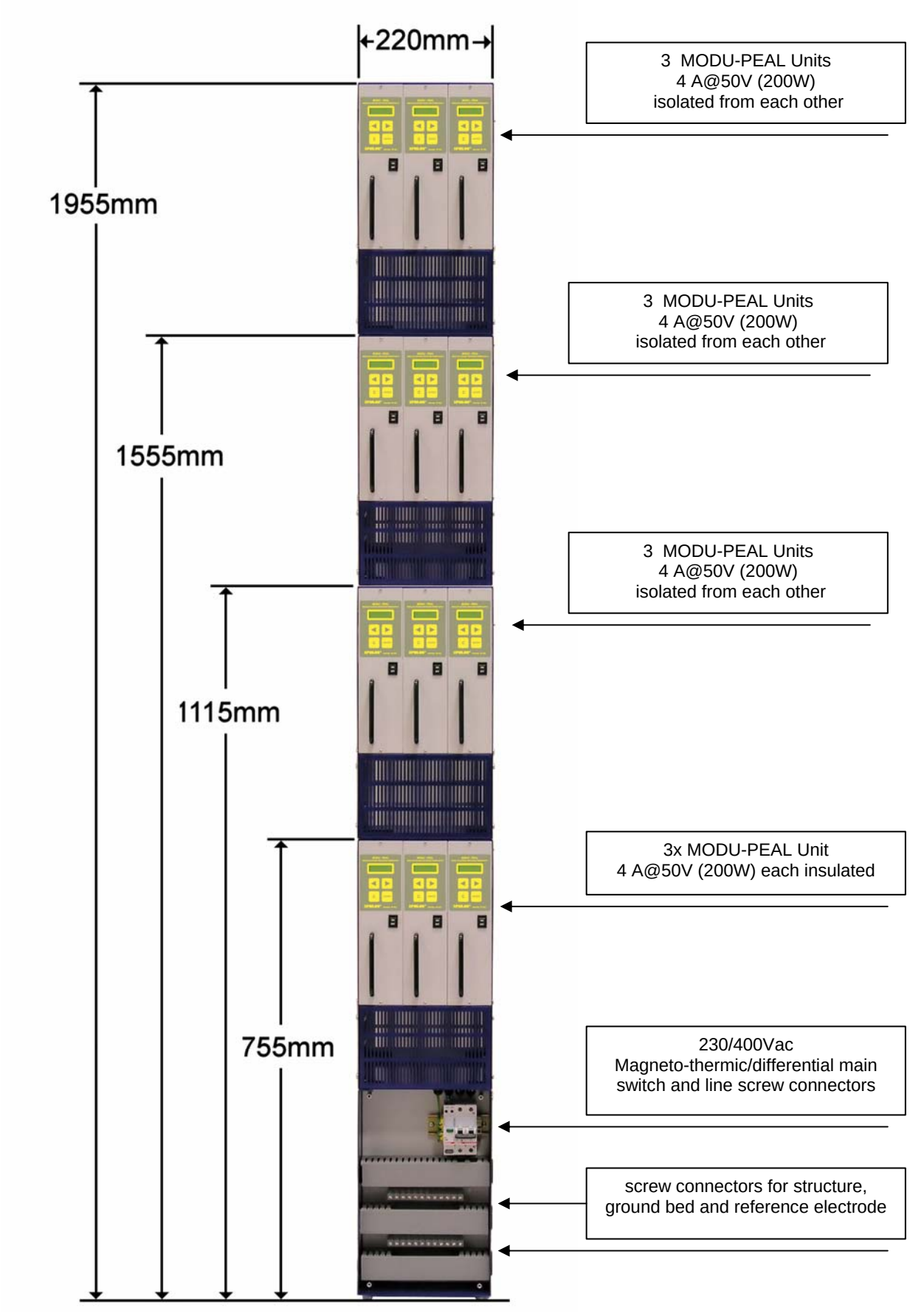


Figure 2 – A completely equipped MODU-PEAL (12 power supply units)

3 – Typical application of MODU-PEAL multiple feeder for Cathodic Protection

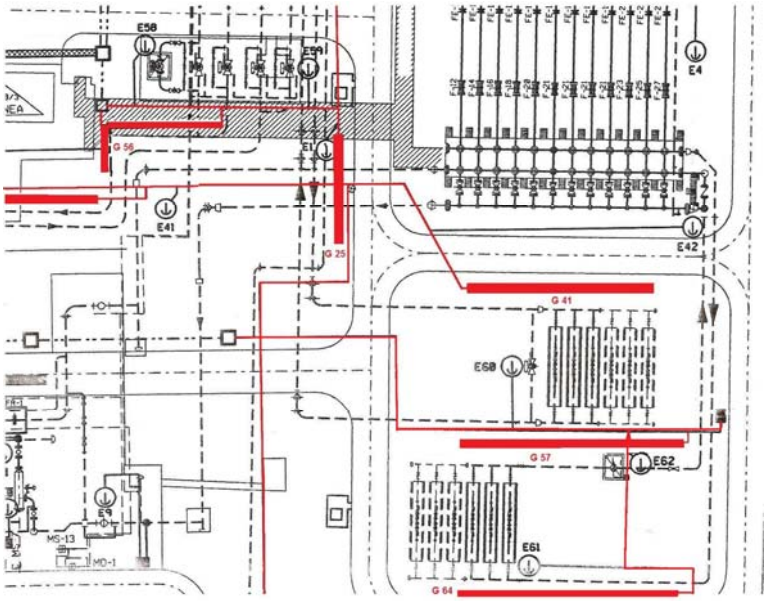
A complex structure, such as a Gas Compressor Station is usually constituted by the following different materials:

- a complex pipeline network, often including big structures such as column filters, valves, measurement lines, turbines, service oil tanks etc;
- a grounding system, nowadays constituted in the majority of cases of galvanised steel ribbons
- various other structures, including the reinforcement of concrete foundation and other structures
- fire-fighting water circuit and relevant hydrants, if made of metallic materials

When gas pipelines are to be cathodically protected among such a kind of structures, the presence of different metals and extraneous electrodes (e.g. the pipeline itself, going out from the area of a Gas Compressor Stations or Oil Pump Stations) is unavoidable.

This is the typical case where a certain number of groundbeds are to be placed in appropriate position so that the cathodic protection current is spread out just locally where it is mainly needed.

In some circumstances, an update of supplementary groundbeds in various positions is only made once the effect of the existing ones has been verified.

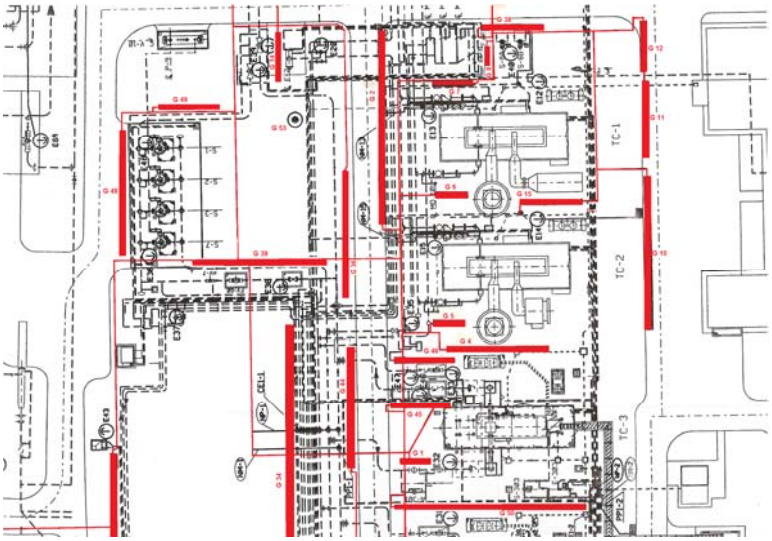


G = Groundbed, NM = Negative measuring cable, NP = Negative Power cable , E = Permanent Reference Electrode

Figure 3 – Sector of a Gas Compression Station

Figures 3 and 4 show typical CP circuits within some complex structures (in this cases portions of a gas compressor station) where a certain number of Groundbeds (G) have been installed to obtain the so-called “local or global CP”.

A Cluster of groundbeds is grouped and fed through a unique positive cable. The currents are then set in a way that the CP current is enough for the local cathodic protection, and the calculated life duration of the groundbed is not exceeded.



G = Groundbed, NM = Negative measuring cable, NP = Negative Power cable , E = Permanent Reference Electrode

Figure 4 – Sector of a Gas Compression Station

In the particular case indicated in the Figures 1 and 2, the parameters indicated in the following Table 1 have been fixed.

CPS N.	Current A	Voltage Volt	Groundbed Code	Current A	NP Code	NM Code	Permanent Reference Electrode Code n.	- Von (Volt)
TR 4 - 620	**3,5**	**15,4**	G 4	0,76	**NP 2**	**NM 2**	**E 35**	**2,43**
			G 5	0,57				
			G 36	2,17				
TR 5 - 621	**3,6**	**11,6**	G 2	0,86	**NP 3**	**NM 2**	**E 40**	**1,48**
			G 6	0,22				
			G 8	0,36				
			G 15	0,43				
			G 38	1,73				
TR 9 - 625	**2,5**	**5,48**	G 23	0,18	**NP 5**	**NM 13**	**E 4**	**1,28**
			G 24	0,26				
			G 25	0,71				
			G 41	0,22				
			G 56	0,41				
			G 57	0,57				
			G 64	0,15				

Table 1 – Electrical parameters for some sections of a Gas Compression Station

It should be noted that, from a statistical analysis made on tenths of these structures, more than 80% of the total current provided by a single CPPS has been found to be at an average value around 2 A.

The current required for each groundbed is quite small, so normally these plants are realized with a number of CPPS lower than the groundbeds installed; for example: 6 CPPS (8A/50V each) and 25 groundbeds installed.

To share and to regulate the current on each groundbed, the plant is provided with a variable resistor (500W) for each groundbed. A cabin that contain these resistors is shown in Figure 5.

Figure 5 – Traditional cabinet with resistors to distribute different currents to the groundbeds

More precisely the feedback signal to the CPPS cannot be supplied by a single reference electrode; the CPPS works in Constant Current Mode. The overall CP level, tested on the reference electrodes, is reached by a manual regulation of the resistors. Of course during operation, the balance of the groundbeds currents may change, so it is foreseen a periodical inspection (every few months), to verify and to eventually re-set the CP current for each groundbed. This regulation can only be obtained by manually operating on the variable resistors.

Regulation by resistors is a dissipative method that causes a high electrical energy consumption and generates a temperature increase in the equipment.

By using the MODU-PEAL, each groundbed (or small group of them) can be fed by a single CPPS and it is possible to close the signal for the feedback loop on a reference electrode, so the CPPS can

operate in Constant Potential Mode (eventually + the Base Current - Ib). The work-point set for each groundbed/reference electrode system is automatically kept constant during time by the MODU-PEAL ; periodical inspections can be scheduled more seldom.

The overall cost of the equipment is lower when using the MODU-PEAL; it is no more necessary to provide the variable resistors and their cabinet which is indeed quite expensive and must be properly and carefully designed and realised.

5 – Conclusion

A new CP feeder has been produced which combines flexibility, lower cost, modern techniques with the remote control of the parameters perfectly integrated in the apparatus.
The usefulness of such an equipment has been derived from the experience of many different Gas Operators, which are seeking for better techniques and economically advantageous solutions; the MODU-PEAL has been conceived to meet the above said requirements.
When CP of Complex Structures is involved, the use of modular CPPS, such as the MODU-PEAL is the best technical-economical solution; it realises a great flexibility and, in the same time, a more reliable control of the Cathodic Protection System.

Reference Standards

EN 14505 : 2002 - CP of Complex Structures
EN 13636 : 2003 - CP of buried Tanks and related piping
EN 50162 : 2004 - Protection against corrosion by stray current from direct current systems
EN 12954 : 2001 - Cathodic protection of buried or immersed metallic structures – General principles and application for pipelines