Modulo 2:

Riferimento a linee guida	FORM N.: 6 PROGRAM EVALUATION FORM
3	Nome programma:
	HV APPLICATIONS AND MEASUREMENTS
3	Responsabile programma
	Prof. Giancarlo Pesavento
3	Obiettivi specifici del programma
	The term "high voltage" applies conventionally to the range above 1000 V and technical applications requiring high voltages are extremely numerous and widely different. In practice, nowadays, the problems are more often dealing with the behaviour of materials in presence of high fields rather than with the application of very high voltages since the levels used particularly for the power transmission will stay most probably unchanged for several years to come. Understanding of physical phenomena taking place requires skills in several branches like electrostatic fields calculation in various configuration of practical interest, gaseous and liquid electronics and the knowledge of the characteristics of the insulating materials. The research program covers different topics both on the physical and on the metrological side, having in mind, in both cases, the interest for practical applications.
3	Progetti in corso
	Project 1: Electrostatic application for the abatement of gaseous effluents For over 25 years there has been a close co-operation in the research field of electrostatic precipitation with the Direction of Studies and Research of ENEL (Italian Electrical Authority). A significant result based on the scientific competence gathered over this long period has been the introduction of pulse energisation in the electrostatic precipitators; this technique allows • better collection efficiency when ashes being produced exhibit a high resistivity • reduced influence on operation in case of mechanical misalignment of the electrodes • greater flexibility for the operation of power plants. Based upon the long experience in this field, the main interest has been now concentrated on the development and design of electrostatic filters being used in for air conditioning of building and in industrial plants for the abatement of pollutants in the exhaust gases. **Project N. 2: Plasma catalysis** Plasma is usually intended as the fourth status of matter, namely the gaseous phase which contains a significant percentage of electrons, ions and atoms with different degrees of excitation and free radicals. Plasma can be obtained by different techniques and among the various possibilities the utilisation of electrical discharges (corona) has proved to be of noticeable interest in view of practical applications. The plasma being produced is in a status of non equilibrium and can be very effective to catalyse chemical reactions initiated by the reactive species already present and namely electrons, ions and free radicals. This Project is carried out in close co-operation with the Department of Chemical Sciences and the area of investigation can be subdivided into three main topics:

a) analysis of ionic reactions in the process of catalysis by means of non thermal plasma for the treatment of organic volatile compounds (VOC). The experiments are carried out mainly in air at ambient temperature and atmospheric pressure. This activity is under way since several years resulting in the production of several scientific reports. Tests are carried out typically inside a reactor of cylindrical shape with an arrangement cylinder-wire with several types of applied voltages ranging from DC to impulse of both polarities. The study has been concentrated on VOCs of various types, mainly hydrocarbons and organic chloride and fluoride compounds.
b) evaluation of the interaction of non-thermal plasmas with liquid materials. This activity for which the University of Padova has financed a research grant for two years is now at the initial stage .
c) study of possible synergy between plasma and chemical catalysis for the treatment of volatile organic pollutants. This activity has been recently financed by the University of Padova.

Project 3: Impulse voltage metrology

High voltage technique has a big impact at industrial level on testing of power apparatus where, in most cases, it's the factor which determines the overall dimensions of the insulating systems. The matter of HV generation has reached a peak of interest in the 70ties in conjunction with the idea being pursued at that time also in Europe of the necessity , within short times, of a transmission grid with a nominal voltage around 1000 kV. Large laboratories were built at that time in France (Les Renardières), in Italy (Suvereto), UK, Montreal (Canada), Brazil etc.. However, due to a variety of factors, in Europe the prediction for the voltage rise was completely abandoned and most laboratories were physically dismantled, due to the high running costs, poor utilisation factor and lack of perspectives for the near future. After that the interest has moved more into the area of development, testing and optimisation of apparatus for the existing voltage levels. The attention was then focused on the practical problems of the measuring systems. In fact, in the HV field, due to the practical impossibility of using successfully the standards already available for the low voltage measuring systems, the standards being widely used were "consensus standards", based on long series of tests carried out in various laboratories. In view of the general application of quality relevant ISO Standards it was decided at IEC level to deal with the HV measurements with the same procedure used in the low voltage range. This decision called for a long series of intercomparison and round robin tests to assess the status of the various measuring systems being proposed. The task resulted to be particularly difficult for the case of impulse voltages for which there is no standard available and the qualification of a measuring system has to pass through a procedure which foresees the determination of the scale factor with standard procedures by using DC or AC voltages and then the extension of this scale factor to the time scale in the range of use (μs). This can be done by already known techniques both in the time domain (step response) and frequency domain, with various difficulties when carried out in practical conditions within a HV lab.
At the same time there has been a substantial change in the recording systems connected to the low voltage side of the dividers; analogue scopes were in most cases abandoned in favour of digital ones. However, despite their excellent performance in terms of nominal resolution and sampling rate, it became evident that in several cases their characteristics were not adequate to assure the required accuracy for impulse testing mainly due to integral and differential non linearities of the A/D converters. The studies have dealt with the problems of qualification of complete measuring systems passing through the various phases of development of a reference measuring system based on a 500 kV ohmic divider developed by the Manufacturer according to our design.
The validity of the choice has been tested within a series of round robin tests at international level sponsored by the Commission of the European Communities – Standards, Measurements and Testing Programme - and co-ordinated by the HV laboratory of the University of Helsinki acting in its role of National calibration Laboratory.
For the digital scope, the problems which have been addressed refer to their qualification, both

static and dynamic, with special regard to the use of general purpose machines whose characteristics can be improved by using oversampling to reduce the noise and improve the vertical resolution.
By using the available laboratory facilities an activity has been pursued also in relation to the physical aspects of the phenomena which are connected with the propagation of a discharge. A contribution has been given to the use of standard air gaps still widely used in testing labs mainly for check of the calibration of the approved measuring systems. An investigation has been carried out both with sphere-sphere to analyse the influence of humidity under impulse voltages and with rod-rod gaps under DC applied voltage.

Project 4 : Partial discharge metrology

Partial discharge (PD) measurement is believed to be the most useful diagnostic technique to assess the presence of weak point in an insulating system arising either from faults in the design stage or from poor treatment of the insulating system (presence of voids in the cast). Due to the different permittivity of these impurities and to the reduced breakdown voltage of the voids, the internal field is usually sufficient to cause the gap to break down. Current pulses associated to PD are known to have extremely fast rise and fall times so that the requirement for a measuring system to reproduce these quantities faithfully would be extremely tough. It is quite common therefore to measure the associated charge. This can be obtained by performing a so called pseudo integration in the frequency domain.
In view of the qualification of these measuring systems required by the relevant international Standards, an analysis has been carried out to evaluate their characteristics and in particular the problems associated to the calibration procedure and to the calibration of the calibrators themselves. Also in this field there has been a close interaction with IEN and CESI in performing national intercomparison of available calibrators and the participation to a round robin test again sponsored by the European Community and co-ordinated by PTB – Braunschweig.
Main problems still under investigation refer to the repeatability and reproducibility of PD measurement when passing from controlled conditions in the calibration phase to the situation of testing of large apparatus in HV laboratories.

Project 5: Application of artificial intelligence for the diagnostic of insulating systems, namely cast resin transformers.

PD measurement can be very useful but its interpretation is usually very difficult. It is common practice to fix a PD value for the acceptance of an apparatus and for this purpose the point which matters could be the accuracy of the determination of this quantity. However, when a PD measurement is performed afterwards during the life of the item, a variation will normally take place, due to the electrical and thermal stresses. A question of utmost importance in this case is not strictly related to the accuracy of the measurement but to the possibility of interpreting the data with respect to the following questions:

- location of ionisation activity
- type of discharge
- possible damage being induced
- assessment of potential risk and decision in order to the maintenance action being required.

Having these aims in mind, it is obvious that the accurate evaluation of the maximum PD value is not sufficient and does not convey the sufficient information. The aim of work under development intends to exploit various techniques already used in the field of artificial intelligence to extract as much information as possible from the analysis of the partial discharge patterns. The study is directed in particular the to insulation systems of cast resin transformer which are vulnerable to these defects and which present difficulties of analysis due to the deformation of PD signal being introduced by the complex electrical network associated to the windings.
The measuring system which has been developed is based on a wide bandwidth recording system

	with the possibility to acquire with a high time resolution up to 500 pulses superimposed to the AC supply voltage. The work has the aim to classify these pulses in relation to the shape to form clusters which could be possibly associated to events taking place in the same location. Having separated the various sources, a parallel investigation is focused on the possibility to determine the position and to establish whether it is a discharge between adjacent turns or in the main insulation to ground.
4.b	Risorse personale
	❖ **<u>Prof. Massimo Rea - (Full Professor)</u>** • Honorary Member of the Council of the International Society for Electrostatic Precipitation • Member of Scientific Committee of the International Symposium on low temperature high pressure plasmas • Member of the Scientific Committee of the International Advisory Committee of the International Symposium on Non Thermal Plasma Technology ❖ **<u>Prof. Giancarlo Pesavento - (Associate Professor)</u>** • Secretary of Technical Committee 42 “Tecnica delle prove ad alta tensione” of CEI (Comitato Elettrotecnico Italiano); • Member of the CIGRE WGD1.33 (former WG33.03) “HV Testing and measuring techniques” • Member of IEC international working groups dealing with the revision of IEC Standard 60060-1 “HV test techniques – Part 1: Definitions and test requirements”, IEC Standard 60060-2 “HV test techniques – Part 2: Measuring systems”. • Convenor of IEC Woking group for the revision of IEC 60052 “Voltage measurement by means of standard air gaps” • Member of ISH (International Symposium on High Voltage Engineering) Scientific Committee ❖ **<u>Prof. G. Zingales – (Professor Emeritus) – retired in 2002</u>** • Member of Technical Committee 42 “Tecnica delle prove ad alta tensione” of CEI (Comitato Elettrotecnico Italiano); • Member of Technical Committee 38 “Trasformatori di misura” of CEI (Comitato Elettrotecnico Italiano); • President of IEC Technical Committee 38 “Instrument transformers” • Member of Central Metrological Committee • President of Technical Commission “Energy Meters” of IMQ • Member of TC 4 "Measurement of Electrical Quantities" and of TC 7 "Measurement Theory" of IMEKO • Member of ISH Steering Committee • President of “SIL - Integrated Laboratory System S.r.l.” • Referee for the journals: "Measurement" e "Transactions of the Institute of Measurement and Control" ❖ **<u>Dr. Renato Gobbo - Researcher</u>** ❖ **<u>Claudio Ceretta – PhD Student since 2005</u>** ❖ **<u>Dr. Alessandro Scroccaro – PhD Student from 2001 to 2003</u>** ❖ **<u>Technical Staff : 1 person</u>**
5.b	Risorse finanziarie

	Financial support from the University has always been rather scarce and hardly sufficient to cover the running costs; in addition, being connected up to a certain extent to the number of people acting inside the research group, it has been cut quite sharply over the last years due to a substantial reduction of the staff acting in this field. The average funding through this channel has been of the order of 6600 € per year; specific research activities connected with the topics listed above have been granted a financial support as indicated in the following: Project N. 4 - PRIN 2000 - € 39250 Project N. 5 - PRIN 2004 - € 57300 In addition the HV Laboratory carries out a testing and development activity on behalf of industries mainly from the surrounding territory but also from various regions of Italy. The average income for these test activity has been on average 60000 € per year over the period being considered and about 40% of this total can be used to support the activity of the Laboratory, particularly for calibration purposes and acquisition of new equipment.
6	Risorse materiali
6.a	The HV Laboratory has been built in 1966, followed in 1973 by a second smaller Lab. The available equipment consists of: ➢ 2.4 MV impulse generator - 50 kJ ➢ 1 MV impulse generator - 18 kJ ➢ 500 kV – 150 kVA HV transformer ➢ Additional resistors and front capacitors to produce both short fronted impulse voltages (LI) and switching impulses with front times up to 600 µs ➢ 2.4 MV capacitive damped voltage divider for impulse and alternating voltages ➢ 700 kV ohmic divider ➢ 500 kV fast ohmic divider ➢ Screened cages for low level measurements ➢ Digital oscilloscopes with sampling rate up to 2.5 GS/s ➢ High accuracy digital recorder Dr. Strauss - 10 bit – 100 MS/s – overall accuracy 0.7 % - DKD calibration ➢ RIV measuring system with coupling capacitor up to 350 kV ➢ PD measuring system Biddle with PD coupling capacitors up to 150 kV ➢ Schering bridge with 300 kV compressed gas standard capacitor ➢ HV diode with reverse voltage of 1200 kV, smoothing capacitor and measuring resistor for DC voltage of 600 kV ➢ Image converter – intensifier camera with time exposure down to 10 ns ➢ DC and impulse generators of various types, including DC plus superimposed pulses, for the production of corona discharges within the reactors for the abatement of pollutants in gaseous phase. In addition, to assure the traceability of the instrumentation and to support a calibration activity for industrial measurements: ➢ Climatic room with standard ambient conditions ➢ Standard multiratio Tettex voltage transformer – Maximum voltage 40 kV – 50 ppm uncertainty ➢ Standard Siemens multiratio current transformer – 200 ppm uncertainty ➢ Tettex electronic instrument transformer comparator Mod. 2767 ➢ Fluke calibrator Mod. 5500A ➢ High accuracy multimeter HP 3458A ➢ Power Analyzer Yokogawa PZ 4000 ➢ Power Analyzer Lem - Norma D4000 ➢ Electrometer Keythley Mod. 6514

	➢ Standard Energy Meter Landis&Gyr
7	Rapporti con altri istituti di ricerca a livello locale, nazionale e internazionale
7.a	The activities pertaining to Project N. 2 are carried out in co-operation with personnel of the Department of Chemical Sciences.
7.b	With reference to the activities related to Project N. 2 there is a frequent cooperation with the following Research Institutes: • Eindhoven University of Technology: Institute of applied physics • Eindhoven University of Technology: Department of electrical engineering • CNRS: Laboratoire de physique des gaz et des plasmas • University of Tokyo: Department of electrical engineering • Polish Academy of Sciences: Centre for plasma and laser engineering Activities connected with Project N. 3 are in cooperation with: • IEN – Istituto Elettrotecnico Nazionale G. Ferrraris – Torino • PTB - Braunschweig - Dr. Klaus Schon • CESI – Milan – Dr. Rizzi and Ing. Cherbaucich • University of Helsinki – HV Laboratory .
9	Altre attività rilevanti per la ricerca, a livello di Programma
	Organization of ➢ Hakone X: 10th International Symposium on high pressure, low temperature, plasma chemistry – Padova, August 23-27, 2004.
11	Prodotti della ricerca

11.b

RESEARCH PRODUCTS	2001	2002	2003	2004	2005	Total
Journal papers						
Chapters in book						
Books/Notes/Reports						
Proceedings of Conferences	3	2	1	2	4	12
Patents						
Other			1			1

11.c	1. **E. Marotta, A. Callea, G. Scorrano, M. Rea, C. Paradisi**.:" Non-Thermal Plasma Chemical Process for the Abatement of Volatile Organic Compounds*",Oral presentation at 10th European Symposium on Organic Reactivity, Roma, 25-30 luglio 2005.* 2. **R. Gobbo, G. Pesavento**: " Procedure for the check of integral non linearity of digitizers",12th ISH Bangalore, 2001, Paper 7.8. 3. **R. Gobbo, G. Pesavento et al.** " Evaluation of the characteristics of calibrators and PD measuring systems according to IEC 60270", 12th ISH Bangalore, 2001, Paper 6.71. 4. Commission of the european communities - Standards, Measurements and Testing programme - Intercomparison of impulse charge measurements - Project SMT4-CT95-7501, 1998 "Traceability and mutual Recognizability of impulse voltage measurements" – March 2003.

5. **R. Gobbo, G. Pesavento**: “ Evaluation of convolution to assess the performance of impulse dividers”, XIV ISH Beijing 2005, Paper J-8.

PUBLICATIONS

1. **C. Paradisi, F. Poli, G. Scorrano, F. Luise, M. Rea**: “ Use of Corona Electric Discharges for Destruction of Volatile Organic Compounds (VOCs) in Air. Influence of VOC on DC Corona Characteristics and Ozone Production”**,** *XXI Congresso della Società Chimica Italiana – SCI 2003, Torino, 22-27 giugno 2003.*

2. **C. Paradisi, F. Poli, G. Scorrano, F. Luise, M. Rea**:” Influence of VOC pollutants in air on DC corona characteristics and ozone production***”,*** *HAKONE IX, 23-27 August 2004.*

3. **F. Fujii, Y. Arao, M. Rea**.:”NOx treatment test by two-stage ESP model”, *HAKONE IX, 23-27 August 2004.*

4. **E. Marotta, A. Callea, G. Scorrano, M. Rea, C. Paradisi**.:” Non-Thermal Plasma Chemical Process for the Abatement of Volatile Organic Compounds***”,****Oral presentation at 10th European Symposium on Organic Reactivity, Roma, 25-30 luglio 2005.*

5. **E. Marotta, A. Callea, M. Rea, C. Paradisi**:” Abatement of atmospheric organic pollutants by means of electrical corona discharges”, *Poster presented at 10th EUCHEMS-DCE International Conference on Chemistry and the Environment, Rimini, 4-7 settembre 2005.*

6. **R. Gobbo, G. Pesavento**: " Procedure for the check of integral non linearity of digitizers", 12th ISH Bangalore, 2001, Paper 7.8.

7. **R. Gobbo, G. Pesavento**: " Rod-rod gaps under DC voltage“, 12th ISH Bangalore, 2001, Paper 7.25.

8. **R. Gobbo, G. Pesavento et al.** " Evaluation of the characteristics of calibrators and PD measuring systems according to IEC 60270“, 12th ISH Bangalore, 2001, Paper 6.71.

9. **R. Gobbo, G. Pesavento, A. Scroccaro** “ Qualification of analog PD measuring instruments according to IEC 60270 Standard, 12th IMEKO TC4 International Symposium on Electrical Measurements and Instrumentation, September 25–27, 2002, Zagreb, Croatia.

10. **G. Pesavento, A. Scroccaro**: La qualificazione dei sistemi di misura nell’ambito della nuova normativa: requisiti e prove “, IEN G. Ferraris – La nuova normativa per la misura delle scariche parziali, - Giornata di studio - Torino, Dicembre 2002 – pp. 1.1- 1.22.

11. Commission of the european communities - Standards, Measurements and Testing programme - Intercomparison of impulse charge measurements - Project SMT4-CT95-7501, 1998 “Traceability and mutual Recognizability of impulse voltage measurements” – March 2003.

12. **R. Gobbo, G. Pesavento**: “ Evaluation of convolution to assess the performance of impulse dividers”, XIV ISH Beijing 2005, Paper J-8.

13. **R. Gobbo, G. Pesavento, A. Scroccaro**: “ Calibration reproducibility in partial discharge

	measuring systems", XIV ISH Beijing 2005, Paper J-42.