Development and Requirements of a New High Power Laboratory

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Abstract**--Ormazabal has installed a new High Power Laboratory in Spain. The requirements for the output of the High Power Laboratory are defined by the equipment ratings to be tested and Standards testing procedures.**

The High Power Laboratory main equipment must withstand short circuit conditions continuously, so the development of this kind of installation is a complex process where the specifications for the design of the main equipment are very special. In this article, the most important ratings, circuits and characteristics of this equipment can be found.

The control system fulfills all the safety and operation technical requirements adapted to the particular needs of the laboratory and its main equipment. In this new High Power Laboratory automatic and remote operated systems are employed to maximize performance and improve the safety of the installation for test operators.

The measuring system has been developed to meet all the technical requirements according to IEC Standards and STL procedures.

Index Terms**—Certification, Laboratories, Power Distribution Testing, Research and Development, Standards, Test Facilities.**

I. Introduction

Ormazabal is one of the most important suppliers in the European Union of equipment and services for the medium voltage electric distribution network. Since its foundation in the year 1967 has been aware of the strategic importance of applied research for the development of its own technology, offering products and services of high quality to their clients and to consolidate their position on the world's technological frontline.

In the frame of this strategy, Ormazabal has created the Research and Technology Centre (CIT by its Spanish initials), in which all the research activities of Ormazabal are integrated. This new centre includes all the necessary equipment for experimental research related with Medium Voltage equipment, including a High Power Laboratory (HPL), the only one in Spain, as well as the conventional High Voltage, Temperature rise, Mechanical and Environmental laboratories. The CIT supposes a qualitative jump in the research capabilities of Ormazabal that will contribute to the development of safer, more efficient and environmentally respectful products.

In the new CIT of Ormazabal essential aspects for the development of more advanced products will be developed, such as, evaluation of technologies and experimental confirmation of theories and simulation models. The CIT will also offer its services for research testing to the technological scientific sector, and for development and certification of products to the Ormazabal Business units as well as the rest of the electric sector.

The HPL will allow Ormazabal to perform different tests that, up to now, there were done in other European laboratories not having a laboratory of this type in Spain. The Laboratory has capacity to issue test certificates of the tested products according to the standards and values that are indicated below.

With date of the 20/02/2009, "Entidad Nacional de Acreditación" (ENAC) has agreed to grant the accreditation (Nr.697/LE1521) to ORMAZABAL CORPORATE TECHNOLOGY according to the Standard UNE-EN IEC/ISO 17025 for the electric equipment testing.

ENAC, is the organism designated by the Spanish Administration to evaluate the technical competence according to the international standards. The accreditation is the international scale established tool that allows the accredited entities to issue test reports and certificates with an internationally recognized mark.

ILAC (International Laboratory Accreditation Cooperation) it is the organism of mutual recognition of accrediting entities. This allows that the ENAC accreditation is automatically accepted the in more than 50 countries as, COFRAC (France), DATech/DAR (Germany), UKAS (United Kingdom), RvA (The Netherlands), PCA (Poland), TURKAK (Turkey), A2LA (American Association for Lab Accreditation - USA), etc….

TABLE I
Scope of Accreditation of The New High Power Laboratory

TEST OBJECT	TEST	STANDARD
High-voltage/low voltage prefabricated substation	Dielectric tests: Power Frequency, Lightning Impulse Temperature-rise tests Functional tests Short-time and peak withstand current tests Internal arcing test	IEC 62271-202:2006.
Alternating current disconnectors and earthing switches	Dielectric tests: Power Frequency, Lightning Impulse, PD Temperature-rise tests Measurement of the resistance of circuits Operating and mechanical endurance tests Short-time and peak withstand current tests Test to prove the short-circuit making performance of earthing switches	IEC 62271-102:2001 IEC 62271-102: 2002 CORRIGENDUM 1 IEC 62271-102: 2003 CORRIGENDUM 2 IEC 62271-102: 2005 CORRIGENDUM 3
High-voltage switches for rated voltages above 1 kV and less than 52 kV	Dielectric tests: Power Frequency, Lightning Impulse, PD Temperature-rise tests Measurement of the resistance of circuits Mechanical operation tests Short-time and peak withstand current tests Making and breaking tests	IEC 60265-1:1998. IEC 60265-1:2000 CORRIGENDUM
High-voltage Alternating current circuit-breakers	Dielectric tests: Power Frequency, Lightning Impulse, PD Temperature-rise tests Measurement of the resistance of circuits Mechanical and environmental tests Short-time and peak withstand current tests Making and breaking tests	IEC 62271-100:2008
A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	Dielectric tests: Power Frequency, Lightning Impulse, PD Temperature-rise tests Measurement of the resistance of circuits Mechanical operation tests Short-time and peak withstand current tests Internal fault test	IEC 62271-200: 2003
High-voltage switchgear and controlgear	Dielectric tests: Power Frequency, Lightning Impulse, PD Temperature-rise tests Measurement of the resistance of circuits Short-time and peak withstand current tests	IEC 62271-1:2007
Power transformers	Routine tests	IEC 60076-1:1993. IEC 60076-1/A1:1999 IEC 60076-1:1997 CORRIGENDUM 1
	Dielectric tests: ▪ Separate source AC ▪ Induced AC ▪ Lightning Impulse	IEC 60076-3:2000. IEC 60076-3:2000 CORRIGENDUM 1
	Ability to withstand short circuit	IEC 60076-5:2006

II. HIGH POWER LABORATORY

The High Power Laboratory (HPL) was a project that supposed a great milestone for the development of the Spanish electric industry due to its singularity and testing capabilities, being the only one able to reproduce the nominal and short circuit conditions of the electrical networks. It has been developed in collaboration with KEMA Transmission and Distribution Consultancy (KEMA-TDC). The collaboration started during the definition phases, and continued through design, commissioning and training of Ormazabal employees. A general layout of the HPL can be seen in Fig.1.

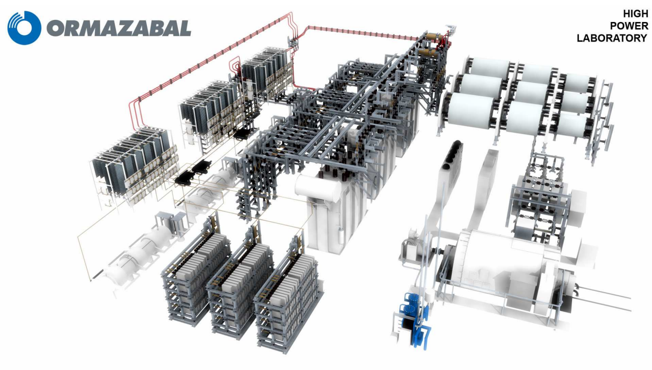


Fig. 1. 3-D View of the High Power Laboratory Installation

A. HPL Layout

The basis of the HPL is a Short Circuit Generator (SCG) with a rated short circuit power of 2500MVA. This very special machine, designed for this purpose, supplies the power needed for the tests. Taking into account the responsibility of this equipment, all kind of parameters are monitored on-line and remote controlled from the control room of the High Power Laboratory (Fig. 2).

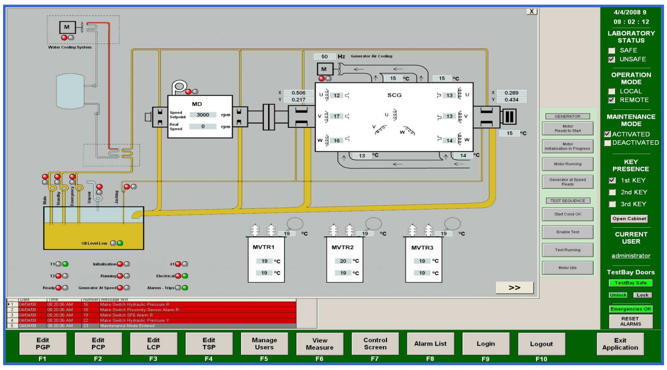


Fig. 2. Short Circuit Generator monitoring

A tri-phase motor (M) of 1,500 kVA speeds the 40 Ton rotor of the SCG up to 3,000 or 3,600 rpm, depending on the frequency required for the tests (50 or 60 Hz). Once the nominal speed is reached, an electrical disconnection is produced in the motor and an excitation or super-excitation current is sent into the rotor (up to 14,000A). The current induced in the stator in these conditions, taking into account circuit impedance, can reach 58kA at 14kV, values which define the maximum power available for testing.

TABLE II
TECHNICAL CHARACTERISTICS OF THE SHORT CIRCUIT GENERATOR (SCG)

Nominal voltage (kV):	14
Maximum voltage (kV)	15,4
Number of phases:	3
Frequency (Hz):	50/60
Nominal speed (RPM):	3000/3600
Connection:	Y
Power (MVAr initial)	2500
Current Test @ 0,1 s (kA)	58

Completing the test circuit (Fig. 3), flowing downstream from the SCG, and conveniently separated, the following equipment can be found: the general circuit breaker of the generator (BB), the make switch (MS), current limiting reactors (L) and power transformers (TR) to adjust voltage.

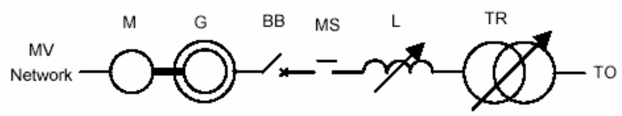


Fig. 3. High Power Laboratory Scheme

The most important function of the Generator circuit breaker is to switch off the power supply immediately in case of faults, in order to prevent any damage to the short circuit generator or the rest of the HPL.

TABLE III
TECHNICAL CHARACTERISTICS OF THE GENERATOR BACK-UP BREAKER (BB)

Nominal Voltage (kV):	24
Nominal Current (A):	10400
Number of phases:	3
Frequency (Hz):	50/60
Short circuit current (kA):	100

The Make Switch is used to energize the test circuit of the short-circuit laboratory by connecting the high power transformer to the test circuit. In order to perform all required tests, the exact moment of switching should be accurately controlled.

TABLE IV
TECHNICAL CHARACTERISTICS OF THE MAKE SWITCH (MS)

Nominal Voltage (kV):	24
Nominal Current (A):	1500
Test Current (kA):	63
Number of phases:	3
Closing time (ms):	<10
Short circuit current (kA):	100

The Current Limiting Reactors, in combination with the voltage transformer, are used to perform tests with different currents. The reactors are air-core type and the reactance value is manually selected.

TABLE V
TECHNICAL CHARACTERISTICS OF THE CURRENT LIMITING REACTOR (L)

Nominal Voltage (kV):	14 kV
Reactance range (ohm):	0-11
Number of phases:	3
Frequency (Hz):	50/60
Ventilation:	AN

The Medium Voltage Transformer bank is used to feed the test circuit of the laboratory, so they are able to withstand symmetrical as well as asymmetrical short-circuit currents. From the design point of view, these transformers have different voltage settings with optimized short-circuit impedances.

During the design, special attention has been paid to obtain a minimal degree of distortion of the power frequency recovery voltage and the ratio X/R.

TABLE VI
TECHNICAL CHARACTERISTICS OF THE MEDIUM VOLTAGE TRANSFORMER (MVTR)

Primary Nominal Voltage (kV)	14
Secondary Nominal Voltage (kV):	4x6
Ventilation:	ONAN
Number of phases:	1
Short-circuit Power (MVA):	1333
Total Short-circuit Power (MVA):	4000

Additionally, one Low Voltage Transformer (LVTR) is required to perform low voltage tests in the laboratory. In this case a three-phase transformer has been chosen, including different voltage settings.

TABLE VII
TECHNICAL CHARACTERISTICS OF THE LOW VOLTAGE TRANSFORMER (LVTR)

Primary Nominal Voltage (kV)	14
Secondary Nominal Voltage (V):	760/550/440
Number of phases:	3
Secondary current kA/kApeak	96/220
Short-circuit Power (MVA):	200
Connection Group:	Dyn 5

The circuit is completed by different resistive, inductive and capacitive impedance banks for the simulation of different circuit charges, to adjust the testing current value and power factor.

Also, in every switching test, the Transient Recovery Voltage (TRV) must be adjusted by changing the TRV control circuit, consisting of an oscillating circuit located near to the test object.

The configuration of the different test circuits is done automatically through pneumatic remote operating mechanisms, which can be controlled from the control room as can be observed in Fig. 4.

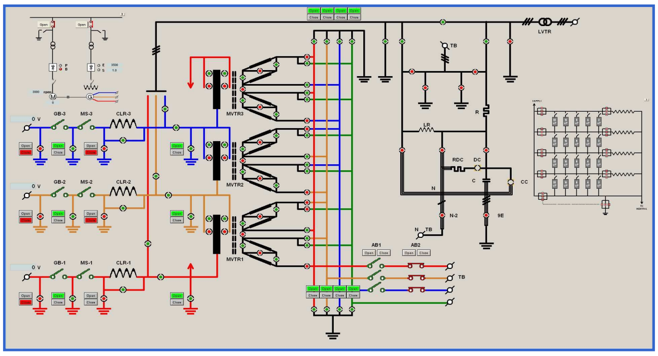


Fig. 4. Pneumatic remote operation of switches from Control Room

B. *Measuring & Laboratory Management System*

For the control of the laboratory and test measurements the following two independent systems are installed:

- Laboratory Management System (LMS)
- Measuring system.

The Laboratory Management System monitors and controls all primary and secondary/auxiliary equipment and components in the laboratory, while the Measuring system measures and reports the test results. The relevant test data from the LMS is also reported in the Measuring system.

The task for the LMS is to manage all equipment and systems in a safe and efficient way. Information on all laboratory equipment is available for the operator in the

Control Room. Also, the LMS has the possibility to generate warning messages and block the Laboratory in the event of dangerous circuit settings or configurations.

For the LMS the following sub-systems can be distinguished (see Fig. 5):

- Protection System: The function of the protection system is to protect the primary installation and to limit the impact of a fault. The protection system is a separate autonomous functioning system. Information from the protection system will be sent to the control system.

- Control System: The function of the control system is to control the primary equipment. From the control system it is possible to load settings in subsystems as; sequence timer, motor and generator control system, and measuring system. However, the current test sequence is not controlled by the control system.

- Sequence Timer: The sequence timer is a separate autonomous function system, to control a test sequence with very accurate timing. The test sequence is defined from the control system and loaded in the sequence timer. During the real test, the sequencer starts and controls all the operations required in the primary components to perform the tests, including the triggering of the measuring system.

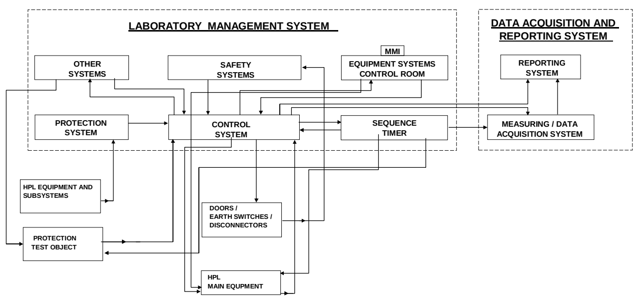


Fig. 5. Scheme of LMS and Measuring System

In general, the Measuring System consists of two subsystems:

- Signal measuring system (block I+II+III in Fig. 6)
- Data acquisition & reporting system (block IV in Fig. 6)

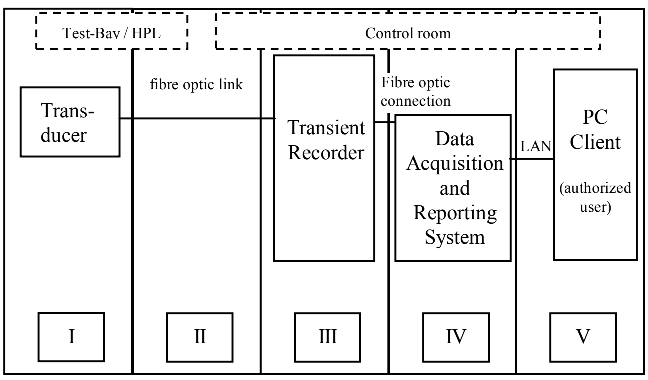


Fig. 6. Detailed Subsystems of the Measuring System

In the signal measuring system, all signals obtained from the transducers are conditioned and transferred to a panel in the control room through optical links and coaxial cables. The transient recorder stores all raw data. In the following figure (Fig.7) the measuring signals available in the HPL can be observed:

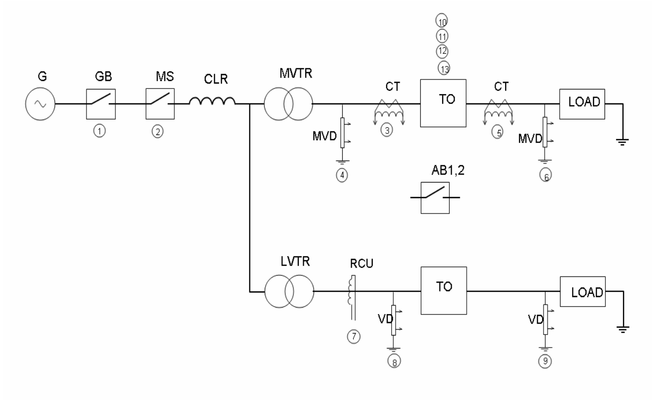


Fig. 7. Layout of the Measuring System

The data acquisition and reporting system, by means of a very high resolution Transient Recorder, makes the measured signals available in a numerical format with very high accuracy. However the main advantage is that the data can be automatically processed and analyzed providing standard and structured information that can be used for different kinds of analyses or comparison. (Fig. 8)

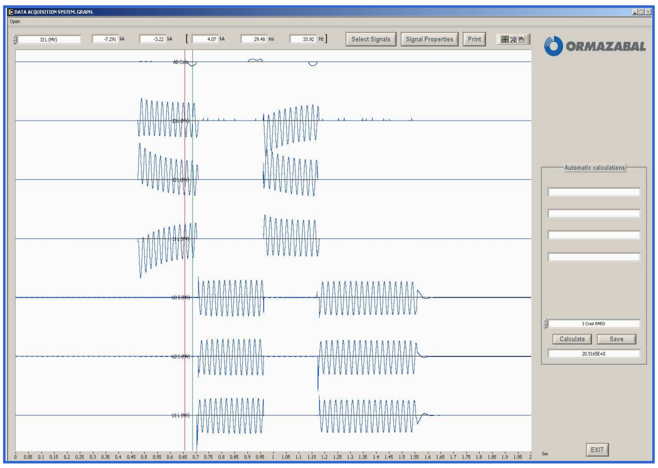
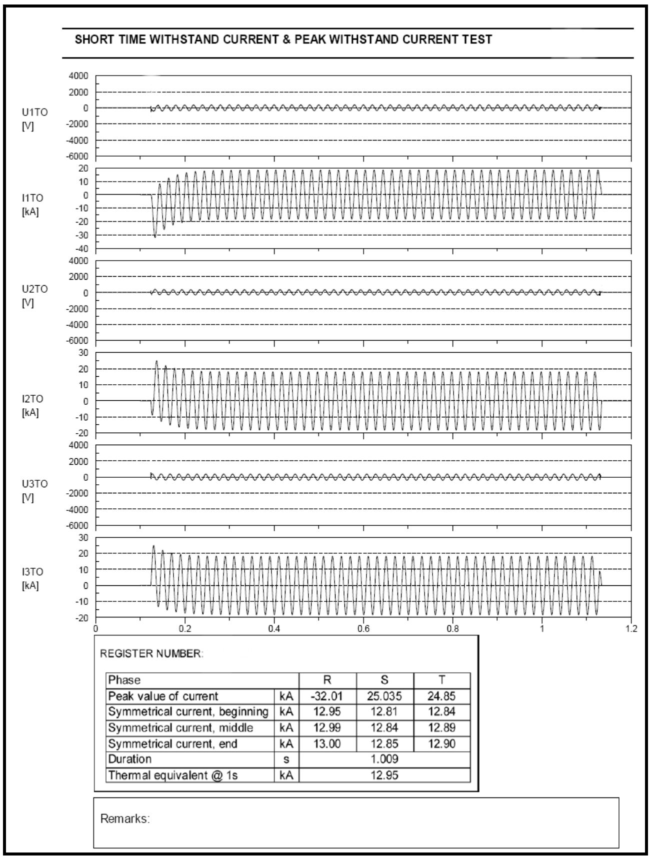


Fig. 8. Screenshot of HPL Data Acquisition System

Another very important advantage of the Measuring System of this High Power Laboratory is that the test quantities are evaluated in a very short time and can be automatically summarized in a computer aided test report.



Phase		R	S	T
Peak value of current	kA	-32.01	25.035	24.85
Symmetrical current, beginning	kA	12.95	12.81	12.84
Symmetrical current, middle	kA	12.99	12.84	12.89
Symmetrical current, end	kA	13.00	12.85	12.90
Duration	s	1.009		
Thermal equivalent @ 1s	kA	12.95		

Fig. 10. Example of one automatic Test Report

C. Technical Requirements and Standardization

The STL Task Group A, published a Technical Report in September 2004 called "HARMONISATION OF DATA PROCESSING METHODS FOR HIGH POWER LABORATORIES"[1]. This document indicates methods for the automatic evaluation of test quantities in high power laboratories and indicates their background. The idea behind the described methods is to keep as close as possible the manual analysis procedures mentioned in IEC publications and in other STL guides.

In this STL report, the criteria for applied algorithms were defined to ensure accuracy, analyzing the measuring errors which were neglected in the past when manual graphical methods were employed. It became clear that certain values were almost impossible to calculate correctly with the manual method (graphical method), and although theoretically were not correct, were commonly accepted as correct.

The automatic processing of test results improves repeatability by excluding the human factor, thus providing a better agreement between test results from different high power laboratories.

In the Measuring system of the HPL, in order to improve the uncertainty of the measurements and the performance during comparison tests, the methods proposed by STL were used. See example in Fig.9.

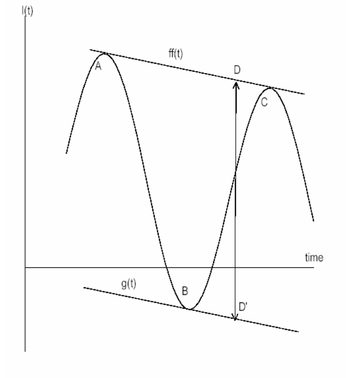


Fig. 9. Three-crest method to calculate r.m.s. value of the a.c. component

Currently, inside the IEC Technical Committee TC42 (WG12), there is a new standard under development, IEC 62475 Ed. 1.0: High-current test techniques: Definitions and requirements for test currents and measuring systems – "Proposed Horizontal Standard" [2].

This new standard looks to solve the lack of standardization regarding high current measurements and, for the measurements of high power laboratories, is based on the previously mentioned STL document.

The Measuring System of the HPL fulfills all the requirements of the future Standard as well as:

- IEC 60060 High voltage test techniques [3]
- IEC 61083-2 Digital recorders for measurements in high-voltage impulse tests [4]
- STL Technical report, Harmonization of data processing methods for high power laboratories.

D. HPL Capabilities

Taking into account the technical characteristics of the main equipment detailed previously, the following tests can be performed with the limits specified in the following table (Table VIII).

TABLE VIII
HIGH POWER LABORATORY CAPABILITIES

High voltage Switches & Circuit Breakers	
Short time & Peak Withstand Current:	40kA/3s
Short-circuit Making & Breaking:	20kA/36kV 31.5kA/24kV 40kA/17.5kV
Mainly Active Load Switching:	up to 2500A up to 36kV
Capacitive Load Switching:	up to 100A/36kV
Internal Fault:	40kA/1s
Power Transformers	
Short circuit testing	20 MVA @ 36kV 25 MVA @ 24kV
Low Voltage Switchgear	
Short time & peak withstand current	80kA/1s
Internal Fault:	80kA/1s

III. ACKNOWLEDGMENT

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IV. REFERENCES

Technical Reports:

[1] The STL Task Group A (2004, Sept) "Harmonisation Of Data Processing Methods For High Power Laboratories".

Standards:

[2] High-current test techniques: Definitions and requirements for test currents and measuring systems –"Proposed Horizontal Standard". IEC 62475 Ed. 1.0. (42/250/CDV), Mar, 2009

[3] High voltage test techniques. IEC 60060

[4] Digital recorders for measurements in high-voltage impulse tests. IEC 61083-2

V. BIOGRAPHIES

Iñaki Orue was born in Basauri, Basque Country, Spain, on September 8, 1970. He obtained the Electrical Engineering degree by the Basque Country University in 1996.

In 1997 he started in Ormazabal as Engineer and in 2000 was promoted to Laboratory chief.

From 2004 he has occupied the position of Laboratory Manager in Ormazabal Corporate Technology. He has been in charge of the Technical development of High Power Laboratory Project.

Since 2003 he is member of the Spanish of the Technical Committee CTN207/SC42 related to "high voltage testing techniques". In 2007 he was appointed to WG12 of IEC Technical Committee 42, as technical expert to develop the Standard for High Current test technique.

Javier Larrieta was born in Barakaldo, Basque Country, Spain in 1965. He graduated in Naval engineering in the Basque Country University (UPV-EHU) in 1990 In 2004 he received his Ph.D. degree in Industrial Engineering from the same University.

In 1990 he joined Ormazabal as a materials specialist where he has been his entire professional career. In 1993 he was appointed to laboratory chief and in 2000 was promoted to Technology Manager. From 2004 he has occupied the position of Ormazabal Corporate Technology General Manager.

He has been in charge of the Research and Technology Center project from the very beginning.

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Ian Gilbert (M'2004) was born in Nottingham, United Kingdom in 1973. He was awarded a BSc (Hons) in Materials Science in 1994 and PhD in Materials Science and Metallurgy in 1998 both from the University of Manchester Institute of Science and Technology (UMIST).

After briefly working in the automotive industry he went on to carry out Postdoctoral Research at the University of Newcastle in 1999 and at CSIC-University of Zaragoza, Spain in 2002.

He has been working as a Research Engineer with Ormazabal Corporate Technology since 2004.