European Network of Excellence of DER Laboratories and Pre-Standardisation

Activity Report 2005 to 2008

DERlab

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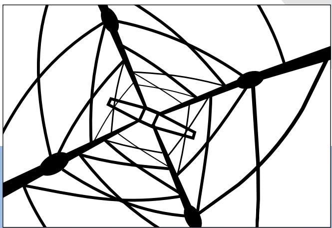
Our Vision

To be the reference-lab in Europe for sustainable integration of distributed energy resources into power systems.

Our Mission

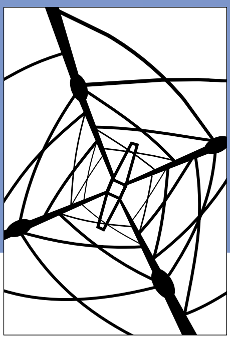
Perform tests, pre-competitive and pre-normative research, as well as training activities, supporting the transition towards more decentralised power generation.



Preface

In the Network of Excellence DERlab, supported by the European Commission, the research institutes from eleven countries have been developing joint requirements and quality criteria for the interconnection and operation of distributed energy resources since the end of 2005. In addition, they prepare testing and certification methods as well as standards valid all over Europe for decentralised power generation. The project partners have now sealed their further co-operation after the six-year research project is completed by founding the DERlab association: they will continue to jointly use the laboratory infrastructure and exchange research results, personnel and know how.

This report presents the activities and opportunities of DERlab and provides an insight into the European Distributed Energy Resources Laboratories.



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Introduction

Currently distributed power generators such as solar power plants and wind turbines feed their electricity – unregulated for the most part – into the public grid at a low-voltage or medium-voltage level. Their increasing number creates new challenges, in particular since currently there are neither harmonised standards nor harmonised interconnection requirements or test procedures for grid feed-in in Europe.

Recent targets for the penetration of renewable energy sources in the European Union demand that the share of energy consumption covered by renewable energy sources should be raised to 20% by 2020. This figure results in a considerable higher power share than 20%, because wind and PV generators have less full load hours than bulk power plants. If the growing DG output is not properly and timely handled, the reliability and the security of the energy supply could decrease.

As more and more decentralised energy resources are integrated in the distribution network, it will be necessary to use laboratory tests to validate the new concepts for analysis, planning, control and supervision of the electricity supply and distribution in order to take these new components into account in the performance optimisation of the whole system.

DERlab is the European Network of Excellence (NoE) of independent laboratories working with the integration of distributed energy resources (DER) into electricity grids and the preparation of related standards and test procedures.

DERlab will provide critical support to the development of a common European research and development platform related with DER integration into power systems, taking into account the needs and concerns of the European utilities and manufacturers. It will also strongly support the consistent development of DER technologies and contribute to the creation of a European competence through highly skilled human resources working at the leading edge of DER technology.

Expected achievements are:

- A distributed world-class DER laboratory for Europe: The objective is to develop a pan-European laboratory, which will be recognised as a leading laboratory in the field of Integration of DER.
- Support for the development of European and international standards: This will be achieved by executing exemplary research activities on specific fields and by initiating new research activities, which aim at providing required technical information and input to the standards.
- Durable networking between European laboratories: DERlab aims at the long-lasting creation of European competence through the establishment of a pan-European expert group in the area of "New DER technologies and their Integration into the Future Distribution Network" consisting of highly skilled researchers working at the leading edge of DER technology.

European Distributed Energy Resources Laboratories Association

Building up the Network of Excellence

Sustainable Networking

In September 2008 the DERlab network partners have founded the association DERlab (which stands for European Distributed Energy Resources Laboratories) as an independent world-class laboratory for the grid-integration of distributed power generation.

By founding the association, the project partners have now sealed their further co-operation after the six-year research project is completed: Even after the end of the public funded project they will continue to jointly use the laboratory infrastructure and to exchange research results, personnel and know how. With this association it is intended to ensure the quality of decentralised power generators and co-ordinate future test procedures at an early stage. Members of the board of the new association are Philipp Strauss (ISET, Spokesperson), Hubert Fechner (arsenal research), and Maria-Luciana Rizzi (CESI RICERCA).

Staff Exchange

The DERlab partners recognize that in order to carry Europe towards its aim to have a truly distinctive role within the international scheme, the community requires high level and motivated staff who are dedicated to achieving this aspiration. As such, DERlab is committed to providing developmental opportunities to equip staff with the knowledge, skills and motivation required to play a part in achieving the Europe's vision.

Within this scope, the capability of supporting the professional development across the partners through networking and the delivery of appropriate training becomes of major importance. In that basis, a framework that enables partners' interaction has been developed and is currently being implemented.

Objectives of such a professional network

- Establish professional development of staff involved
- Boost knowledge/services transfer through dissemination of good practices and tools
- Represent the members at European level, influence knowledge transfer & innovation policies

Survey of Laboratories and Test Infrastructure

The laboratories involved have been developed independently according to the requirements of a great variety of projects in the area of DER. On the one hand this offers an enormous variety of possibilities for testing and experiments in the area of DER. On the other hand this has also led to a situation of fragmentation with a lack of standardisation and compatibility of the laboratories and little knowledge about the infrastructure and testing procedures in detail outside each national scope. To overcome this handicap a data base for systematic and detailed listing of the laboratory facilities and testing capabilities was generated. The list of laboratory facilities enables in the first step the DERlab members and later on other institutions as well having access to the listing to learn from the experiences made by other DERlab members and to assess whether a certain experiment with certain parameters is possible.

This contributes to efficient planning of new projects in a way that tests can be located in the lab most suitable to a specific testing problem in Europe.

DERlab is developing a joint infrastructure in order to reach a common test portfolio and to perform tasks one member alone is not capable to do.

Laboratory description

A survey of European test facilities for DER is provided on the DERlab web site with the objective to support the mutual use of existing infrastructure. Each laboratory is briefly characterised according to accreditation, DG experience, prestandardisation activities and independency from industry and electricity network operators. Furthermore extensive information is available following a common standard format.

DERlab esd
equipment & service database

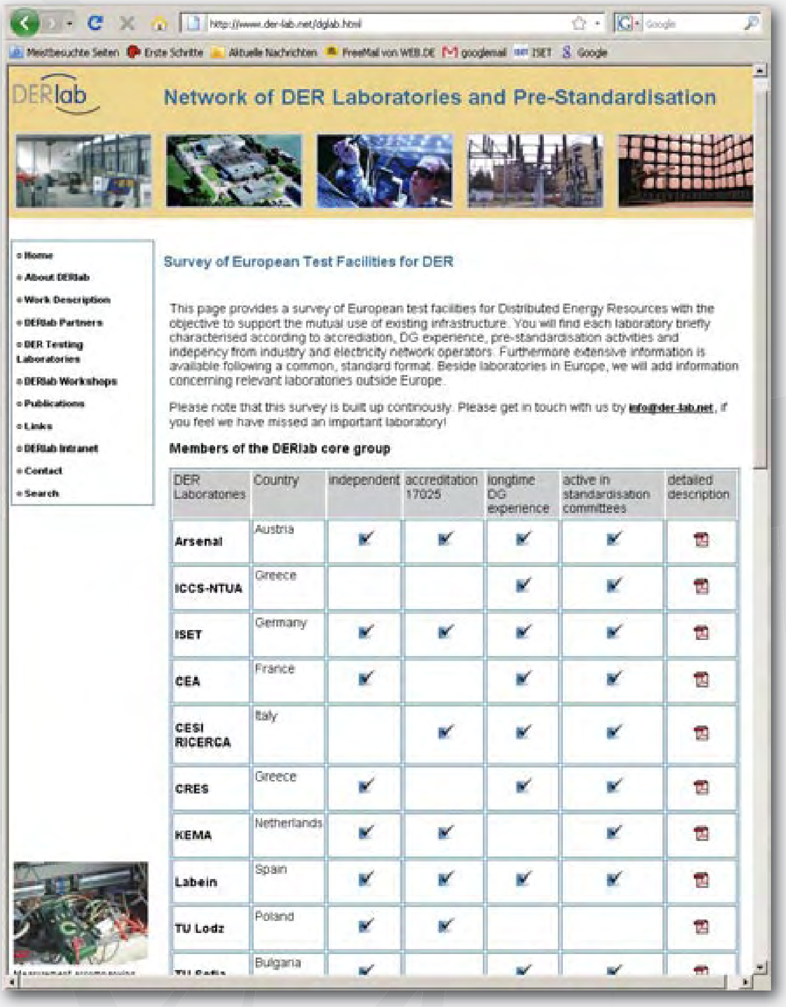
The laboratories of the DERlab members have been developed independently according to the requirements of a great variety of projects in the area of DER. This variety is both a challenge and the chance to offer comprehensive services.

The equipment and testing services available at the partner laboratories are compiled in the data base DERlab esd (DERlab equipment & service data base).

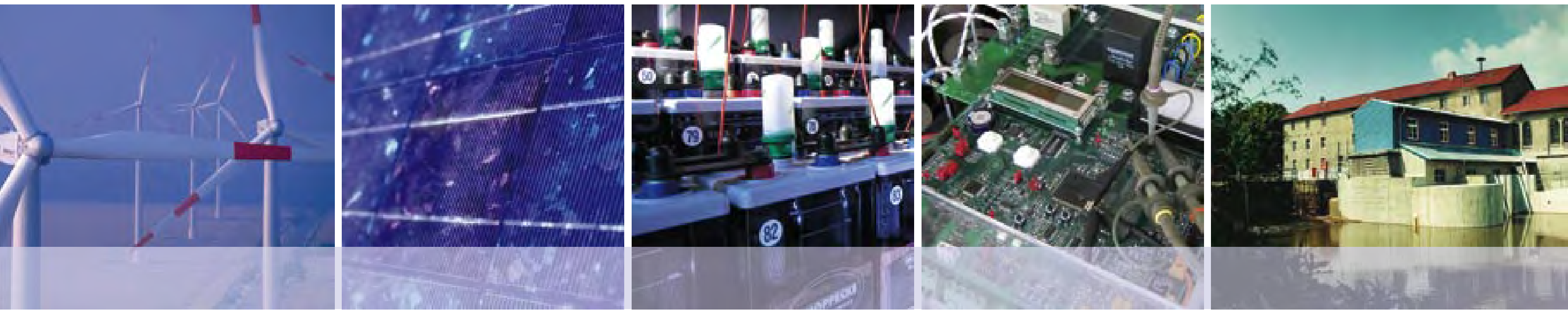
The data base facilitates the integration of the DERlab network by providing a survey of the test facilities and equipment of each partner. This way the experience of single laboratories with specific equipment can be made available for the entire network and it provides the platform for the shared use of equipment and test capabilities.

The DERlab esd contributes to the efficient planning of new projects in a way that tests can be allocated in the laboratory in Europe most suitable to a specific testing problem and will help to plan investigations that could not be carried out by any single partner of the network.

Building up the Network of Excellence



Joint Research



Interconnection Requirements

The absence of a harmonised interconnection standard has been identified as one of the most severe obstacles towards the wide deployment of DER and as a result to the change towards active electricity networks. Addressing this diversity has been set as one of the most important objectives of the research community.

Thus it is also one of the key objectives of DERlab. As a first step for harmonisation DERlab proposed a structure for a European Standard for interconnection of Distributed Energy Resources (EDIS).

A promising collaboration was defined with the recently created working group (WG 03) of CENELEC/TC8X, dealing with the formulation of the technical specification "Requirements for the connection of generators above 16 A per phase to the LV/ MV distribution system". DERlab contributes to this work actively and is also directly participating in the WG03 team.

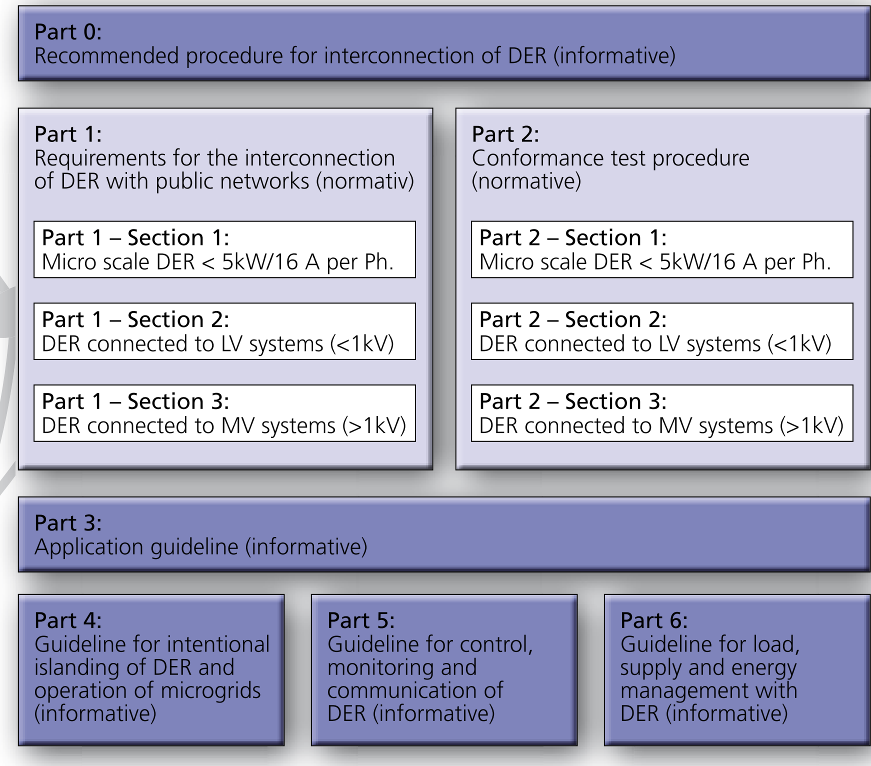
International White Book on the Grid Integration of Static Converters

Greenhouse gas emissions and the dependency of many industrialised countries on fossil energy imports can be reduced by using local renewable energy sources (RES) and distributed energy resources (DER). Distributed generation can increase the efficiency and the security of the power supply system. But the integration of such generation units is a challenge for the efficient commercial and technical aggregation.

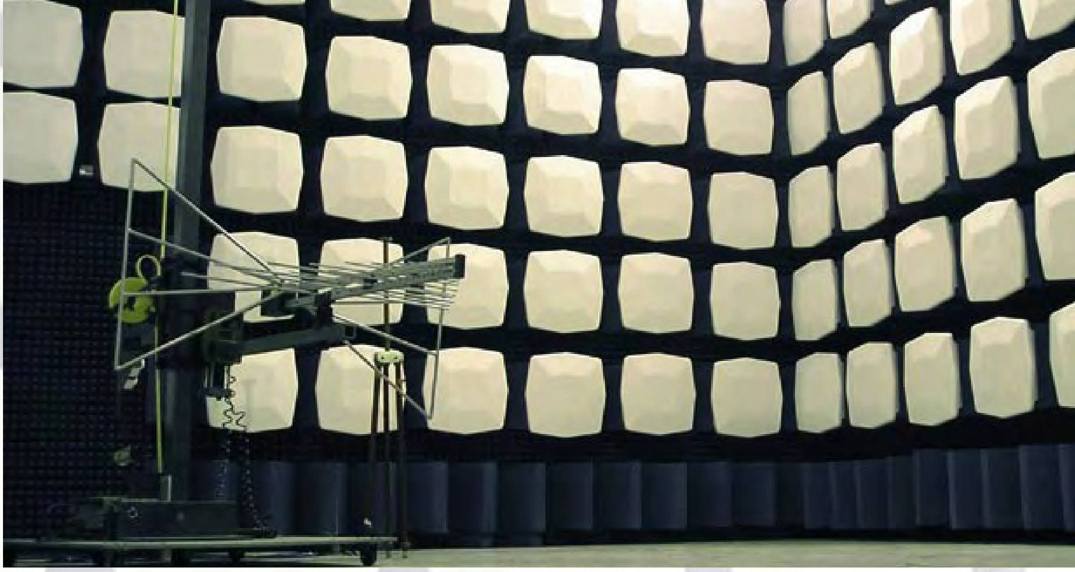
According to related political aims, incentives are offered in some countries that boost DER and RES. In the past, the main objective was to feed-in maximum active power, but in future the need for active participation of DER units by supporting network operation increases. With high shares of DER units they principally should cover also similar control tasks as conventional power plants.

Grid inverters are the key elements to massively integrate distributed renewable energy sources into the power system. In this context DERlab has started the preparation of an international white book for research and standardisation needs of grid inverters.

The developed draft concept is available on the DERlab Internet Portal and is currently being discussed on national, European and international level.



Proposed structure for a European Standard for Interconnection of Distributed Energy Resources



Electromagnetic Compatibility (EMC) of DER Systems

Problem and approach

EMC has been detected as one of the main technical and regulatory barriers for DER integration. In addition to conventional electrical technologies (also potentially "noisy"), DER systems contain digital and power electronic modules for energy conditioning and control, which can generate conducted and radiated disturbances into the installation where they are operating, and can be affected by electromagnetic emissions coming from nearby equipment. An increasing degree of interaction and interference can be produced between different DER systems, grid equipment and loads, taking into account that DER systems are installed at or close to the customer premises (in an industrial, commercial or residential environment).

In recent years, a lot of power performance and power quality tests have been performed on DER equipment, but however little EMC testing has been carried out. This is caused by several factors: proliferation of diverse requirements, lack of harmonised product standards, difficulties for extending the test equipment and methods to MV and HV (for DER at those voltage levels), unawareness of the application of the European EMC Directive to DER by installers and owners, etc.

Trying to improve this situation, DERlab created an internal "Working Group on EMC for DER" to cope with the critical issue of EMC related to DER. Different tasks are still in progress but first results have been collected in a draft Guide Document. The DERlab Guide Document explains the different characteristics, requirements and certification procedures applied to both categories (apparatus and fixed installations) according to the EMC Directive. Even when there is too much work to do on standardisation, the priority for the working group has been to clarify the application of the EMC Directive to DER equipment. Unlike the EMC Directive, EMC standards are not mandatory but a tool to demonstrate presumption of compliance with the Directive (the law).

Once the certification procedures according to the Directive have been understood, the DERlab working group is now developing a critical assessment of the EMC requirements and testing methods established by different national and international standards and regulations. Rather than DER product oriented, the analysis is EMC phenomena oriented. The results will be included in the future versions of the Guide Document, and hopefully, will constitute a valuable input for standardisation product committees. The Guide Document is available on the DERlab Internet website.

Communication with standardisation committees

DERlab supported from the beginning, the project proposal "Assessment of Electromagnetic Immunity and Emission Requirements for Dispersed Generation in LV Networks" of the International Electrotechnical Commission (IEC). This led to the set-up of the Project Team PT61000-3-15 of IEC/ SC77A (convened by CESI RICERCA) in September 2006. DERlab is participating directly in the group with three members, and also actively contributing to this work by sending the results of the DERlab "Working Group on EMC for DER".

The first Committee Draft of the Project IEC 61000-3-15 was issued in July 2008, and comments through the National Committees are expected until October 2008.

Joint Research

Implications of the EMC Directive for DER systems

The new EMC Directive (2004/108/EC), like the old version (89/336/EEC), harmonises the protection against electromagnetic disturbances in order to guarantee the free movement of electrical and electronic equipment (DER systems included) in the European Union.

The systems covered by this law are divided into two categories: apparatus and fixed installations. Depending on the situation, DER equipment can be considered as an entire installation (wind turbine, PV installation, etc.) or an individual apparatus (generating unit, inverter, control/protection device, etc.).

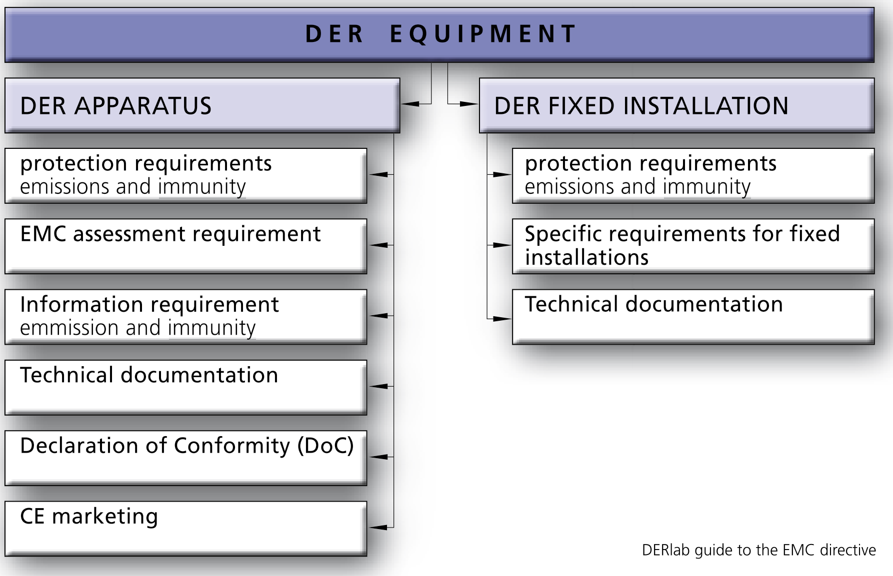
Development and Enhancement of DER Testing Procedures

The penetration rate of DER units in distribution grids and the rated power of the single units will increase massively. This will lead to tighter interconnection requirements and to the necessity of independent testing laboratories with harmonised testing procedures on a high quality level to achieve comparability and confidence.

A crucial contribution will be the formulation of common testing procedures. This is however not a straightforward issue since the procedure specifications in standards usually is not very clear and subject to diverse interpretations. A common view and interpretation is needed on topics as test conditions, measurement or assessment procedures, measurement uncertainty and result recording. Inter-comparison (round-robin) tests between the laboratories involved support this approach.

The availability of appropriate and well-defined testing routines is also a basic prerequisite for the following certification of DER products.

The first step of the inter-comparison tests is focussing on problems related to testing procedures on photovoltaic inverters.



DERlab guide to the EMC directive

Test procedures for photovoltaic inverters

PV inverters may work only if connected to a proper grid and there are several issues related to their operation. Among the relevant issues are:

- Maximum power, which affects the line voltage and the grid capability
- Inverter efficiency
- Harmonics
- Loss of mains protections

For inverter efficiency and harmonics, it is possible to perform the tests in laboratory (using PV panel simulators) and in field (using real PV panels). A number of difficulties arises measuring inverter efficiency - especially at low power - because:

- The lower is the output power, the higher is the harmonics (THD) content.
- Input values are not stable because of the Maximum Power Point Tracker (MPPT) circuit.

Regarding the main-loss protections, islanding may (theoretically) arise when the grid is off or the production equals loads. The inverter output may be tested when a voltage interrupt occurs, but it is also interesting to test the behaviour of the inverter in case of voltage drops.

DERlab decided to focus the testing procedures applied to photovoltaic inverters mainly on aspects related to the interconnection in a distributed generation grid. So, the tests are divided in two levels: interconnection issues including harmonic current measurement, DC current injection, input current unbalances, loss of mains protection and component issues including efficiency measurement and MPP accuracy when PV shadowing occurs.

DERlab is on its way doing a 'round robin' inverter test: two devices will be shipped to the partners. Each of the participants, performing the tests, will

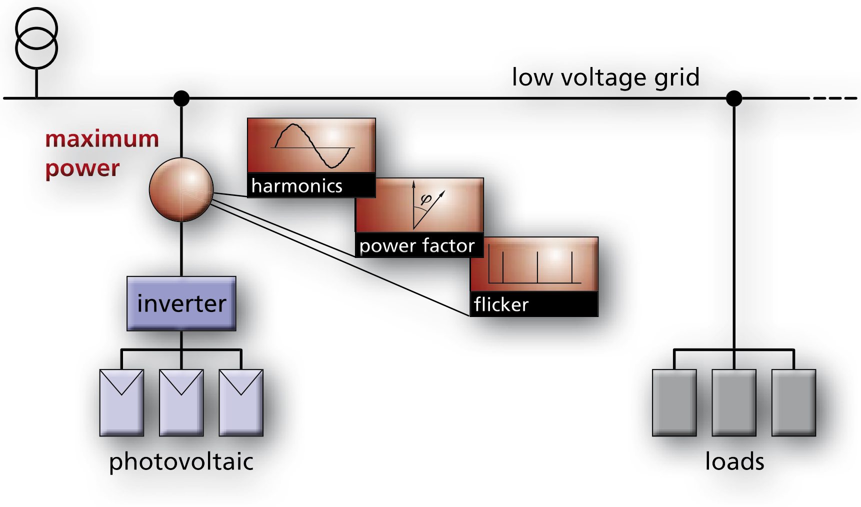
- focus on the problems above mentioned,
- detail his way of testing and
- identify lacking points in the standards.

A detailed description of the tests and related templates for the recording of the results will be produced to facilitate the comparison. This evaluation will lead to harmonised testing procedures and a high quality level in all DERlab laboratories. Furthermore the experiences will serve as input for the pre-standardisation activities.

Coming tests will deal with communication procedures. First considerations have been made on this topic to identify the main points to be developed:

- The product specific standards, if any, are the basis for the tests.
- Communication conformance tests are based on 61850-10.
- System related tests (system integration and commissioning) are project specific and depend on agreement between customer and manufacturer.

The objective of both test series, interconnection of PV inverters and communication of DER units, is to identify lacking aspects of standards and test procedures in order to define proposals to standardisation bodies.

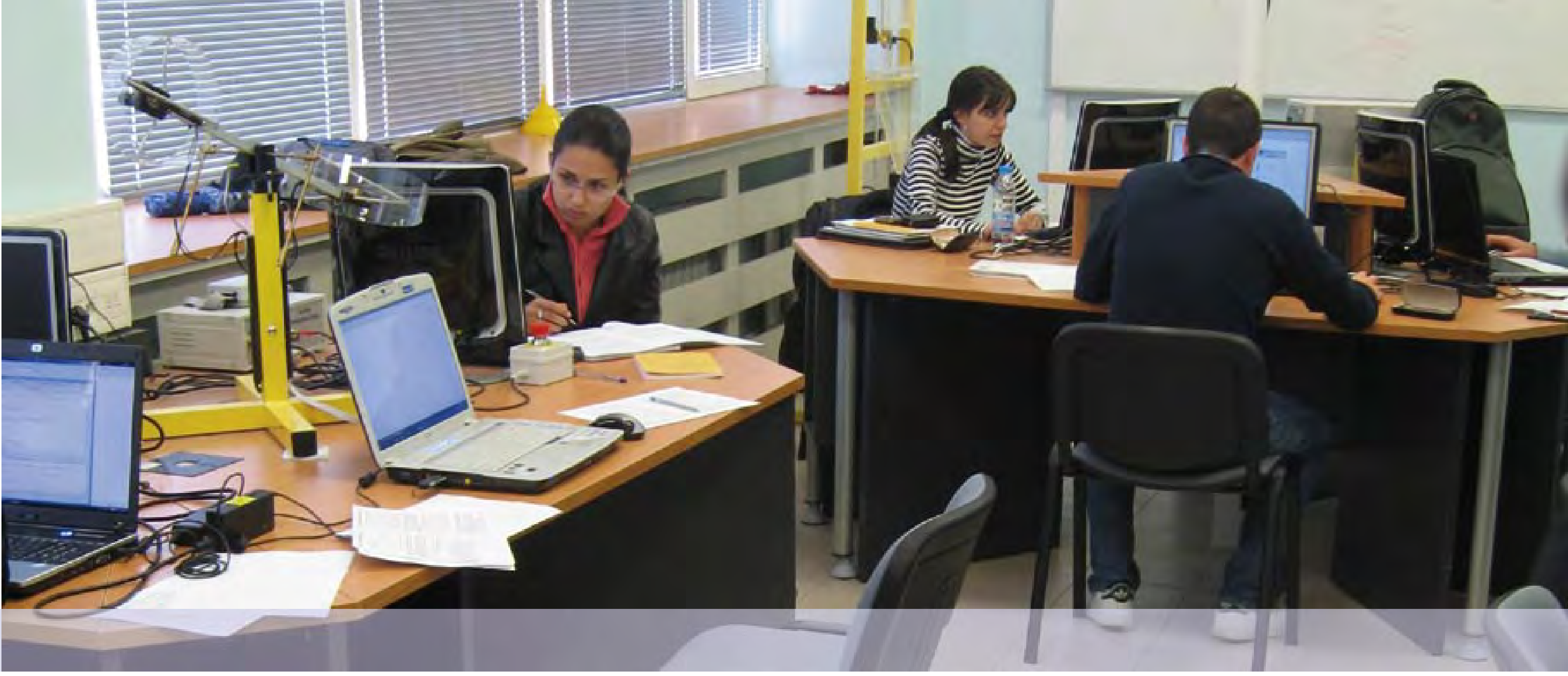


Different impacts on a grid connected PV inverter

Dissemination, Training, Education

DERlab Internet Website

The DERlab website provides information concerning DERlab activities, publications and reports. It is used as key media for dissemination and information exchange. In particular the website provides a survey of European test facilities for DER with the objective to support the mutual use of existing infrastructure. You will find each laboratory briefly characterised according to accreditation, DG experience, pre-standardisation activities and independency from industry and electricity network operators. Furthermore extensive information is available following a common, standard format. Beside laboratories in Europe, information about further international DER test facilities and laboratories is given. This survey is built up continuously. So take a look on www.der-lab.net/dglab.html and get in touch with us, if we have missed your or another important laboratory.



Training and Education

Available educational and training programs were investigated to determine existing and missing topics for DER education in the countries.

The general conclusion is that education and training university courses are oriented towards some aspects of DER, but a global unique point of view for Active Networks is missing. There are no programs attended to advanced power electronic devices and circuits for DER, control information technology for DER, testing and standardisation problems. It is now necessary to introduce among the regular university courses a program able to propose the new vision of energy production and management in the context of the future Electricity Smart Grid.

Education and training activities in Europe were analysed and it is obtained that education courses already cover most aspects concerning DER technologies and related market, economical and environmental issues. Renewable energy sources and distributed generation should not be isolated in a special subject because they have to operate in existing conventional structures. Additional emphasis needs to be placed on standardisation issues, as well as current grid codes and regulations.

DER training courses for the industry – "Electric Energy Systems - University Enterprises Training Partnership" (EES-UETP) are investigated. In future collaborative partnership in these courses is intended.

The feasibility and interest of the setting up of common educational activities, such as a European master on DER, or a contribution to an existing one is studied and discussed. There are two existing European masters related to DER issues:

- "European Master of Renewable Energy" organised with participation of nine European universities, including the University of Kassel, Germany, and the National University of Athens, Greece
- Masters' Course organized by the Politecnico di Milano "RIDEF Energia - Master in Renewable Energy, Decentralisation and Energy Efficiency"

The possibility for organisation of a "European master on DER" in cooperation with these universities will be discussed and examined.

Furthermore a project proposal to support training and education of young researchers from DERlab partners, other universities and industry partners has been prepared and submitted to the European Commission.

Dissemination, Training, Education

DER network: Austria

Since the start of DERlab, arsenal research has been organising Austria's National Conference on "Distributed Generation and Active Energy Networks", regularly including a specific presentation of the ongoing activities within DERlab. By using this platform, comprehensive information on the activities carried out within the Network of Excellence could be effectively disseminated among stakeholders from governmental bodies, research and development institutes as well as the electricity industry. Following these activities, a comprehensive collaboration agreement has been signed with the Association of Austrian Electricity Companies (VEÖ). Its members account for more than 90 % of electricity generation in Austria and the organisation is also coordinating and funding applied research in the field.

Thus, arsenal research could further extend its key position as the national DERlab contact point for activities in the field of smart electricity networks. Furthermore, DERlab is now also well recognised among Austrian stakeholders as the European Network in this field.

In the framework of a national counsellor contract with the Austrian ministry for Innovation, the objectives, activities and research experience are constantly communicated by arsenal research in order to achieve an in-line tuning of the national research programme.

A quite new activity is the new research Cluster "active distribution networks" which brings together all stakeholders in distributed energy resources, which are active in the research field. Coordinated by arsenal research, this cluster will from now on jointly prepare and perform all RTD national projects under this umbrella.

DER network: The Netherlands

To "connect" to the research institutes in The Netherlands with respect to DERlab activities and research in the area of renewable energy sources and distributed generation and promote this within the Dutch industry and the government KEMA performs the following activities:

KEMA is using the existing group "EMVT-vereniging" as a platform to inform and promote about the DER-lab. This EMVT-group is a Dutch "not-for-profit" organisation that has some 40 academic, industry, SME and institute members that are active in the field of applications of power electronics, controls and modelling, relevant R&D development etc. They assemble once a year and also organise / participate at special events like the Dutch Power symposium, power engineering student activities (Hidde Nijland symposium). Members of this group are also active in the national innovative research program (IOP) on power electronics and intelligent networks. KEMA is member of this group and reports on a regular basis.

KEMA, ECN and the universities of Eindhoven and Delft joined their forces in a consortium that builds the power electronics research facility at KEMA. This research facility, together with the real-time digital (network) simulator of TU Delft and the Power Quality laboratory of TU Eindhoven forms "the Dutch extension" of the DERlab. There are regular meeting were we inform each other and decide to participate, either separate or jointly, in national or European research projects. We meet on a regular basis and now started talks to set up a joint (national) research program.

On a national level there is a group of universities, institutes, industries and governmental bodies that deals with "transition to a sustainable energy future". This group is closely related to the EU ETP SmartGrids and the national research programs on energy. KEMA is also part of this group and reports on DERlab activities.

National Information Exchange and Networks

On the national level all DERlab members are establishing and maintaining national networks for an intense information exchange with the national DER-communities and to receive feedback at an early stage. The networks in Austria and The Netherlands exemplify these exchange activities.

All DERlab members act as contact points to coordinate the activities in their European region. Please refer to your contact point for further information about the networks.

EU Member States	DER Network Contact Point
Austria Hungary Czech Republic Slovakia	**arsenal research** Hubert Fechner hubert.fechner@arsenal.ac.at
Bulgaria Romania	**Technical University of Sofia** Anastassia Krusteva krusteva@tu-sofia.bg
Denmark Finland Sweden	**RISØ DTU** Per Norgard vea@risoe.dk
France	**CEA INES Institut National de l´Energie Solaire** Jens Merten jens.merten@cea.fr
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Spain Portugal	**LABEIN-Tecnalia** Eduardo Zabala ezabala@labein.es
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Dissemination, Training, Education

International Information Exchange

The international information exchange and collaboration of DER laboratories supports the sustainable integration of renewable energy sources (RES) and DER in the electricity supply.

The networking takes place in international conferences, the workgroups of international standardisation committees, workshops and direct information exchange between laboratories.

	DERlab members are respresented in following international standardisation committees:
IEC-TC 8	System Aspects for Electrical Energy
IEC-TC 13	Equipment for Electrical Energy Measurement and Load Control
IEC-TC 14	Power Transformers
IEC-TC 21	Secondary Cells and Batteries
IEC-TC 82	Solar Photovoltaic Energy Systems
IEC-TC 88	Wind Turbine Systems
IEC-TC 57	Power systems management and associated information exchange
IEC-TC 105	Fuel Cell Technologies
IEC-TC 99	System Engineering and Erection of Electrical Power Installation in Systems with Nominal Voltages above 1 kV A.C. and 1.5 kV D.C.
CENELEC-TC 8X	System Aspects of Electrical Energy Supply
CENELEC-TC 82	Solar Photovoltaic Energy Systems
CENELEC-TC 210	Electromagnetic Compatibility (EMC)
CENELEC-BTTF 83-2	Wind Turbine Issues

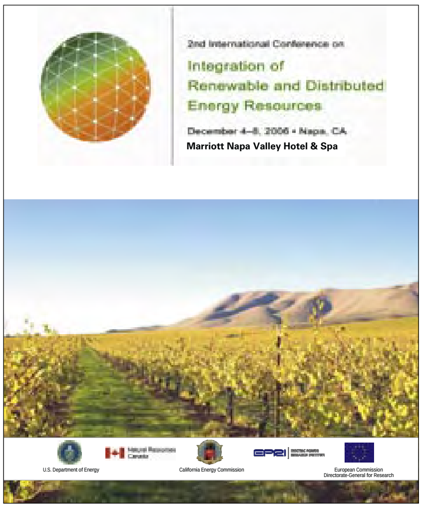
Workshops

A main reason for the establishing of DERlab is the support of European manufacturers, grid operators and other stakeholders by establishing a discussion platform, identifying relevant problems and proposing solutions. Therefore several technical workshops are organised during the course of the DERlab project for the dissemination of the results and to exchange information with the scientific community and the industry.

2nd International Conference on the Integration of DER, Napa (USA)

The first workshop series entitled "DER Laboratories of Excellence, Testing and Standards" was organised at the initiative of DERlab as a pre-meeting event at the 2nd International Conference on the Integration of Renewable and Distributed Energy Resources that took place in Napa (USA) in December 2006. It was co-chaired by Richard DeBlasio (NREL) and Philipp Strauss (ISET). The DERlab Network of Excellence was presented with an oral presentation and a poster exhibition.

In this workshop important discussions between European, US and Canadian research groups took place. It allowed the DERlab partners to collect information on other existing groups and activities in the field, and to come into contact with similar actors, especially in the USA. During the discussion, appeared the need for a white book on the topic of ride-through capabilities of DER inverters. R. DeBlasio, NREL, proposed to work together on this document, which would deal with inverters from the point of view of the network operator: Control issues, behaviour during fault, etc.



European DERlab workshops on Grid Inverters

Following the discussion in Napa a series of workshops has been initiated: Aim of the first two DERlab workshops was the elaboration of the European draft for the international white book on grid inverters. This will be discussed on international level during the third DERlab workshop.

The first "DERlab Workshop on Grid Inverters" took place in Germany, Frankfurt on June 25, 2008 in connection with the CIRED Seminar 2008 on smart grids for distribution. It was the kick-off for writing the "International White Book on the Grid Integration of Static Converters". With more than 50 participants from universities, DER test laboratories, distributed system operators and industry it shows the high relevance of this issue to the scientific community and the industry.

On the second DERlab workshop combined with the "13th Kasseler Symposium Energy Systems Technology" the chapter editors presented the first draft of the "International White Book on the Grid Integration of Static Converters". In parallel sessions the workshop participants pictured their visions 2020 for the tasks of static converters in distribution grids.

The third "DERlab Workshop on Grid Inverters" is combined with the "3rd International Conference on Integration of Renewable and Distributed Energy Resources", 09/12/2008, France, Nice.

Further DERlab workshops will be held in the coming years. Amongst others their issues will cover interconnection requirements and testing procedures of DER.

Our Expertise and Laboratories

The interconnection of DER into power systems is a broad field covering different kinds of electricity generation from solar through wind and fuel cell to diesel generators and different points of view from EMC through safety and protection to storage and network management. Each DERlab partner has its strength in specific DER related areas and together the network builds a cluster of knowledge and experience covering the whole field.

	High Voltage & High Power	Power Quality & EMC	Hybrid Systems & Micro Grids	Power Electronics & Inverter	PV Components & Systems	Wind Components & Systems	Storage Components & Systems
ISET		○	●	●	●	●	○
UKDG	○	○	●	●	○	○	
KEMA	●	○	○	○			
Labein	○	●	●	○			
Risø DTU	○	○	●	○		●	○
arsenal research	○	○	○	●	●		
ICCS/NTUA, CRES		○	●	○	●	○	○
CESI RICERCA	○		●	●	○		○
CEA INES			○	○	○		●
TU Sofia	○	●	○	●	○	○	
TU Lodz	○	●	●	●			

Test and Certification Centre for Distributed Energy Resources

The ISET Test and Certification Centre for Distributed Energy Resources comprises the Design Centre for Modular Supply Systems (DeMoTec), EMC laboratories, outdoor facilities for PV modules and systems, battery test facilities, power electronics labs and laboratories for bio mass powered generators. The DeMoTec hosts a laboratory LV and MV grid with distributed generation units.

This laboratory environment enables tests concerning DER grid integration focussing on grid control, local generator control, power and communication interfaces. A primary role of the hardware environment is to assure the performance and safety of DER equipment and later on help to develop standards. Further the laboratory serves as demonstration and training facility.

Facilities	**Capabilities**
EMC lab	• EMC immunity and emission tests for small appliances and generators
Inverter Test Lab	• Parallel operation of up to 22 inverters, loads and cogeneration plant or other generators may also be included • Power efficiency test • Interconnection and islanding detection tests (resonant circuit and impedance measurement test circuit)
PV-Module Test Field	• Facilities for detailed long-term performance recording available > see also www.pvtestlab.de
Climatic Chamber	• Different sizes and temperature ranges available
Hybrid and Mini-Grid System Test Field (PV/Diesel/Battery/Wind Simulator)	• As part of ISET's Demotec different hybrid system and mini-grid configurations in the power range up to 100 kW can be realised and investigated. Elements for hardware simulation of LV and MV networks are available.
Power Electronics Facilities	• Rapid prototyping system • EMC scanner • Thermographic camera
Simulation	• Alternative power library for SIMPLORER (developed at ISET) • Network analysis tools: Powerfactory, Simcal, ATP-EMTP

UK Centre for Sustainable Electricity and Distributed Generation

Modelling, simulation and forecasting tools

Investigation of new simulation tools for modelling of LV unbalanced distribution networks with micro generation, including both steady state and dynamics. Research on new approaches to planning the development of power distribution networks with growing numbers of diverse generator types.

Protection, control and communication

Focus on novel techniques and algorithms. This involves development and testing of prototype devices. Research is undertaken to identify potential solutions to the integration and control of large numbers of dynamic generation units. Investigation of the most appropriate communications techniques – from real time control through to daily instructions from a network operator.

Management systems for active distribution networks

Proposing alternative active network management schemes to optimise such parameters as power flows, voltage, security and fault level. Development of tools for scheduling of various network and generation control facilities and of procedures for assessing and evaluating the performance of installed schemes for the active distribution management.

Facilities	Capabilities
Real Time Electrical Networks Laboratory	• The Real Time Simulator (RTS) Laboratory facility serves as the underlying vehicle for providing the real-time, Hardware-In-The-Loop (HIL), simulation capability.
80-kW Laboratory Microgrid	• This lab has a 11 kVA gas engine generator, it provides the facility for testing and development with primary plant and secondary equipment.
High Voltage Testing Facilities	• The High Voltage Facilities include a 4 MV impulse generator, 1.2 MV AC source, an 800 kV AC resonant set, 1 MV DC Test Set and a 10 kA, 20 kVA High Current Generator.
Fuel Cell Laboratory	• The Fuel Cell Laboratory provides a domestic scale CHP alkaline fuel cell test system and a PEM based electrolyser unit.
EnergyLINK Laboratory	• Fully configurable and isolated electrical network (up to 1 MW_e) with virtual power supply for emulation of network devices and full connectivity for external generating technology (including G83 compliance testing)

Power Electronics Lab

The Power Electronics Lab fills a unique position among the areas of specialization of other international laboratories. The development and test activities relate to components in the power class of up to 1-3 MW, a voltage level of 3.3 kV and a bandwidth of 2.4 kHz. The programmable converter that forms the heart of the laboratory can create a predefined 'poor-quality network' including, among other things, dips and harmonics. Distributed Energy Resources (DER) tests will be carried out upon requests from clients and in accordance with standards such as IEEE 1547. The Power Electronics Lab is complementary to the globally known KEMA High Power and High Voltage Laboratories.

Facilities	Capabilities
High Power Laboratory	• 4 short circuit generators, maximum short circuit power: up to 10.000 MVA three phase scheme, up to 5.800 MVA single phase
High Voltage Laboratory	• 4 short circuit generators, maximum short circuit power: up to 10.000 MVA three phase scheme, up to 5.800 MVA single phase
Power Electronics Laboratory	• Fully programmable converter to create a custom PQ-grid or load: nominal power 1 MVA in 4 quadrant operation; nominal output voltage 3.3 kV_{rms} (3 phases independently controllable); overload capability 1.25 p.u. during 10 seconds, 3 p.u. during 1 second; adjustable power frequency DC to 75 Hz; harmonic voltage distortion up to 2400 Hz; dips, unbalance, voltage and frequency variations, interruptions.

Microgrids Integration into the Distribution Network

In the last years, LABEIN-Tecnalia's Energy Unit has been involved in several R&D projects related to Distributed Energy Resources (DER) and Microgrids. A facility for the development and demonstration of DER technologies has been set up.

Projects:
LABEIN-Tecnalia's microgrid will be integrated with other similar systems into the Medium Voltage (MV) distribution grid.

Objective:
Study microgrid interaction with the MV grid in order to foster the development of new products for the electrical grid of the future.

Facilities	Capabilities
Photovoltaic Panels	• Single phase 0.6 kW amorphous silicon PV set • Single phase 1.6 kW mono-crystalline PV set with 1080 Ah storage • Three phase 3.6 kW poly-crystalline PV set
Wind Generation	• 6 kW wind mill with permanent magnet generator • Meteorological station with anemometer, rain gauge and thermometer
Diesel Generation	• Two diesel generators based on 55 kW prime movers and a 63 kVA synchronous generators
Microturbine	• 50 kW diesel-oil microturbine. The microturbine has a rotational speed of 56000 rpm with a generator that gives 380 V_{ac} at 400 Hz. The output of the generator is connected to a rectifier/inverter 380 V_{ac} at 50 Hz
Grid Simulator	• Power electronics based generation system able to simulate LV electricity grid (transients, harmonics…) • It is composed of two 62.5 kVA 50 kW sources providing a three phase 228/132 V_{ac} 500 Hz output, 456/264 V_{ac} power transformer and a programmable controller
Flywheel	• 250 kVA UPS system, it is able to respond to voltage sags up to 15 seconds at full load
Ultracapacitor	• Ultracapacitor based storage system able to provide electricity to a 5 kW load for 6.5 minutes
Load Banks	• 150 kW resistive load bank • 55 kW resistive load bank • Two 36 kVA reactive load banks
Network Configurator	• All the devices can be connected following different network topologies

Test Facility for Distributed Power Systems Technology

SYSLAB is the test facility for distributed power systems technology at Risø National Laboratory. It includes facilities for testing components, component-system interaction and complete systems.

The facility can handle components up 50 kW and has space and equipment for testing physically large units such as flow batteries and hydrogen production, consumption and storage equipment. SYSLAB is a down-scaled, but true distributed power system with presently three 2-busbar switchboards in 300-700 m distances, providing high coupling and system configuration flexibility. The system includes wind turbines, diesel genset, solar generators, office loads as well as several types of controllable loads.

SYSLAB has very flexible control possibilities since all units in the system are equipped with a dedicated control computer input/output cards installed for measurement at the terminals of the associated unit.

Complex test sequences can be specified and programmed using the distributed control system. The facility can be used in the research on communication requirements and standards for distributed power systems.

SYSLAB is also being used extensively for education and training.

Facilities	Capabilities
System Test	• Complete system performance logging • Local measurements • Distributed and centralised measurement system • Programming of test patterns • Flexible system configuration including communication and power networks
Controller Tests	• Communication logging at each component
Component Testing	• Power quality measurement • Performance measurements • Determination of charateristics • Programming of complex test patterns

Test Centre for System Components for Photovoltaic and other DER Applications

The arsenal research PV and DER components laboratory comprises a comprehensive set of facilities for PV modules and DER inverters, enabling a broad and comprehensive range of tests on equipment.

The laboratory environment includes among others a flexible test stand for grid-connected inverters for PV and other DER applications and facilities for environmental simulation (solar radiation, temperature, humidity, pressure, vibration…). In addition, arsenal research's Power Service Center provides extensive facilities for tests of electrical equipment for LV and MV applications up to the MVA range.

From its position as a recognized test lab, accredited to ISO 17025 and certified to ISO 9001, arsenal research supports its clients during assessment and improvement of quality, safety and performance of their equipment.

Besides laboratory R&D testing and certification, pre-standardisation and training are further key activities to achieve this objective.

Facilities	**Capabilities**
Inverter Test Laboratory	• Testing of PV and DER inverters as well as interconnection equipment and protective relays • Compliance tests according to various standards (VDE 0126-1-1…) • High-precision performance assessment of DR inverters • Maximum power point tracking assessment with programmable PV-Array Simulators • Anti-islanding tests according to international standards (resonance circuit, impedance, etc.) • EMC immunity and emission tests
Photovoltaic Laboratory	• Certification of crystalline Silicon PV modules according to IEC 61215 Ed. 2 • Pulsed and steady state solar simulators up to 1,8 x 2,4 m² • Outdoor performance tests: NOCT, hot-spot endurance test and energy-rating measurements • Mechanical stress tests
Power Service Center	• Power and high-current tests up to 120 MVA, ~150 kA • Medium and High Voltage Lab (600 kV_{rms}, 1,2 MV_{crest})
Generator Test Center	• No-load test, short-circuit test, load characteristic test, partial discharge monitoring, acoustic noise and vibrations, efficiency, temperature rise test
Environment Simulation Laboratory	• Climatic tests, ice-, snow-, wind-, salt mist and corrosive gas tests • Vibration and highly accelerated lifetime testing, IP protection class tests
Power Quality Monitoring	• Assessment of the power quality in distribution networks with DER
Simulation	• General simulation tools: Matlab/Simulink, SimPowerSystems, PSpice/Cadence • Network simulation tools: DigSILENT, NEPLAN

Testing Facilities for Hybrid Systems and Microgrids

The Electric Energy Systems Laboratory (EESL) of the National Technical University of Athens covers the educational and research activities in the area of electric energy systems and offers various degrees of experimental training for students, as part of the relevant courses of Power System Analysis, Power Generation, Power System Control and Stability, Transmission and Distribution Networks, Power System Protection, Renewable Energy Sources, SCADA and Digital Techniques in Power Systems. The Laboratory is active in research for more than 20 years now, closely affiliated to the Institute of Communication and Computer Systems (ICCS).

It has participated in more than 40 research projects, most of which are collaborative EU funded projects.

The Department of PV systems and DG of CRES participates in European research projects and collaborates with local and European industry. The department activities are mainly focussed on the areas of PV and hybrid systems, battery storage and Distributed Generation.

Facilities	Capabilities
ICCS-NTUA	
Protection Relay Testing	• Real Time Digital Simulator (RTDS) facility
PQ Measurements	• Power analyzers, measurement analysis capabilities
Microgrid	• Prototype two-pole microgrid with wind, PV and local storage. Evaluation of control strategies
Simulation	• State-state and dynamic analysis of power systems • Custom analysis software – commercial software: Eurostag, PSS/E, PSCAD-EMTDC
Consulting Services	• Public, industrial & commercial power systems • Grounding systems • RES exploitation – small autonomous systems • Power quality studies
CRES	
Battery Laboratory	• The facility provides capabilities of cycling tests, high rate discharge tests and ripple-current discharge tests under different environmental conditions.
Hybrid System Test Field	• Control strategies for microgrids with high PV penetration • Power quality measurements
Electronic and Power Electronics Laboratory	• Measurement of efficiency, power quality, noise, operating temperature
Module Assembly and Testing Facility	• PV module laminator
Environmental Chambers	• Control temperature, humidity

Distributed Generation Test Facility

CESI RICERCA, supported by National Research and EU Dispower project, implemented a low voltage Distributed Generation Test Facility, that consists of a PV based hybrid system, a solar thermal dish Stirling, an ORC CHP plant fuelled by biomass, a CHP system with a gas microturbine, various innovative storage systems, a flywheel and remotely controllable loads.

The test facility network is highly configurable in order to reproduce grid disturbances and testing islanding operations.

The management system treats generators as distributed resources, supplying services to the grid. Individual generators give response to fast transient dynamics, while central dispatcher coordinates generators according to Power Quality requirements, in order to balance power flow and improve economics (short term forecasting tools are integrated).

The communication system uses different devices and methods: PLC, wireless equipment, wired Ethernet, 61850 protocols etc.

Facilities	Capabilities	
DG Test Facility	• Tests of different generators and grid configurations	350 kW_e, 250 kW_{th}
High Voltage Laboratory	• Dielectric tests on electrical components	4800 kV impulse, 1600 kV_{AC}, 1600 kV_{DC}
Pollution Laboratory	• Assess the behaviour of electrical components in different environmental conditions	150 kV_{AC}, 150 kV_{DC}
Faraday Cage	• Characterisation of electrical components in very clean electromagnetic environment	250 kV_{AC} 50 to 150 Hz 0.1 pC background noise level
Mechanical Laboratory	• Mechanical tests on conductors and insulators	100 m span with 160 kN, 900 kN traction test facility, vibrating table 10 kN 2.5 cm displ.
Superconductivity Laboratory	• Characterisation tests on superconductive materials and devices	Liquid nitrogen cryostat, liquid helium cryostat, all electrical characterisation equipment

INES – French National Institute for Solar Energy CEA/L2S – Laboratory for Solar Systems

Involved in photovoltaic energy for over 20 years, the former GENEC group (now as L2S at INES) is in charge of R&D on renewable energies, with the main objective of reducing the lifetime costs of PV systems. The activities on batteries began in 1990. L2S now involves 25 researchers among which 16 permanent staff.

The general mission of INES/L2S is to perform R&D in the field of photovoltaic components and systems. It is organized in two groups: "PV systems" and "storage systems".

The "storage systems" group tests and validates storage technologies, especially the electrochemical technologies. Particular emphasis is given to the development of innovative management strategies and of prediction tools for determining the costs and values of storage systems.

In DERlab, INES/L2S is coordinating activities on the storage function within other distributed energy resources.

Facilities	Capabilities
Battery Test Benches	• 70 test channels at controlled temperature, 12 V 20 A up to 100 V 700 A
Test Bench for Solar Home Systems	• 16 channels for SHS testing following IEC 62124 procedure (two climates available)
Chemical Laboratory	• Battery expertise after testing, mainly for lead-acid batteries, starting activity on lithium-ion batteries
PV Systems Test Bench	• Outdoor test facility in two different climates
Simulation Tools and Models	• Matlab, Simulink, Comsol/Femlab, P-Spice
Inverter Test Bench	• Up to 10 kW, including PV-UPS inverters
Pumping Systems Test Bench	• 2 test channels up to 5 kW
Electronics Facilities	• Development of electronic devices
Multi-microgrid Facility (under construction)	• Planned capabilities: 100 kW_p PV, 1 MVA transformer

Laboratories for Distributed Energy Resources

The work on the project Network of DER Laboratories and Pre-Standardisation is being carried out in the Laboratory of Power Electronics, in the Laboratory on Renewable Energy Sources, in the Advanced Control Systems Laboratory, in the High Voltage Laboratory and in the Thermal Power Engineering Laboratory.

The work on the project will be supported by the participants from Ministry of Economy and Energy, Bulgarian Institute for Standardisation and Bulgarian Institute for Metrology. The University is actively involved in the work of various technical committees of the Bulgarian Institute for Standardisation (BDS) and particularly participates in the work of BDS' Technical Committee 79 "Electrical Energy".

Area of Scientific expertise:
DER and hybrid RES linked with the related areas: power electronics-design and simulation of AC/DC, DC/AC and AC/AC converters, simulation of wind and water generators, testing of real objects of RES, process control software and architecture on industrial computers, HV testing, determination of thermal efficiency.

Training and education capabilities of all laboratories.

Facilities	**Capabilities**
Power Electronics Laboratory	• Computer aided design and simulation with MATLAB and OrCAD design centre of DC/DC; DC/AC and AC/AC converters. Measurement in real time of electrical parameters of such converters. Measurement of power quality with "Power Quality Analyzer Fluke 434" and "Fluke View Software"
Advanced Control System Laboratory	• MATLAB/SIMULINK simulation/verification of process control software/architecture on industrial computers/controller equipped with appropriate peripheral devices and connected to fast computers, running objects' models as discrete/analogous/heterogeneous programme
Laboratory on Renewable Energy Sources (RES Laboratory)	• Testing of real objects of RES wind generator, photovoltaic, thermal collector. These objects are linked in a hybrid RES system with automatic measurements. The experimental simulation of wind and water generators with motor generator groups is also possible. The automatic meteorological station serves for the estimation of the primary energy potential
High Voltage Laboratory	• HV AC test up to 332 kV_{rms}; HV impulse test up to 800 kV • HV DC test up to 200 kV; High current test up to 35 kA_{rms} • High current test up to 55 kA
Laboratory of Thermal Power Engineering	• Capabilities for determinations of heating value, ash and water content in the different kind of fuels. Capabilities for thermal balance and determination of thermal efficiency of different object. Necessity of device for on-line determination of the dust-concentration in the flow gases, as well as modern device for gas analyses (determination of the O_2, CO, CO_2, NOX, etc. concentrations in the gases)

Electrical Power Engineering Research and Test Laboratory

The Electrical Power Engineering Research and Test Laboratory comprises a number of test facilities that enable both theoretical and experimental studies related to various DER aspects as interconnection, electromagnetic compatibility in the range of power quality phenomena, modern network control systems (incl. microgrids) supporting deployment of DER in distribution grid, verification of DER interconnection schemes, etc.

Area of research studies and tests covers also testing of HV and LV equipment, digital protection relays, EMC of electrical devices, etc.

Measurement equipment is employed in research, expertise and testing services for utilities, power stations and various industrial plants.

Facilities	Capabilities
DER and RES Test Field (PV/Fuel Cells/Microturbine/Battery Storage APF/DSTATCOM/MV/LV distribution grid model)	• DER testing in different real network conditions • EMC studies of DER impact on network performance • Testing of grid active control algorithms • Verification of DER interconnection requirements
Power Quality Lab	• Field testing using high class measurement equipment (TOPAS 1000, MEMOBOX 800) • Emission and immunity testing of LV electrical devices (AC Power Analyser HP 6813B)
HV Testing Lab	• Design and construction of HV impulse generators • HV insulation tests
Lighting and Electrical Equipment Test Lab	• EC 17025 Accreditation
Electrical Protection Relays Test Lab	• Performance and reliability tests
Network Control Systems Lab	• SCADA systems: PRINCE, WindEx
Simulation Lab	• Grid analysis tools: PSCAD EMTDC, MATLAB, LabView, DasyLab, PowerFactory, ATP-EMTP PSCAD library of DERs and power electronics (developed by TULodz)

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