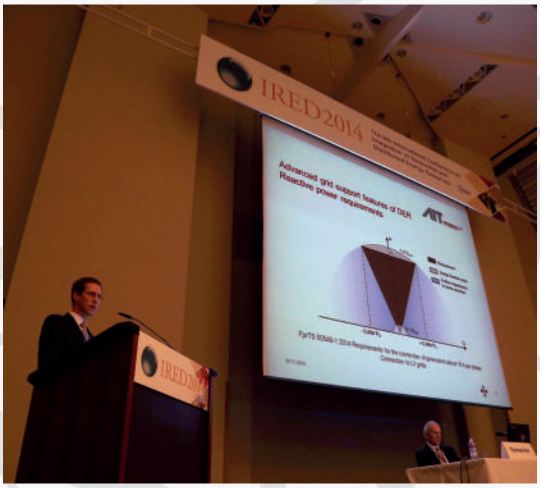
DERlab

European Distributed Energy Resources Laboratories

Activity Report 2014 / 2015



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European Distributed Energy Resources Laboratories

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"We have to move to system verification including not only component testing but also component and system interaction"

"Although the challenge is huge, we will continue this effort in pre-standardisation"

Foreword

The speed of changes in the energy landscape is increasing fast. The trend towards a green and sustainable energy system is evident and unstoppable. Our perception of variable renewables changes as well: from being a nuisance that has "to conform" to the existing market and grid operation codes towards becoming a system supporter by unlocking new possibilities through power electronic interfaces. These fundamental changes of power delivery systems and their operation demand a major overhaul - beyond incremental improvements.

On 23 October, 2014, EU leaders committed themselves to reducing greenhouse gas emissions by at least 40% by 2030 and increasing energy efficiency and the share of renewables by at least 27%. However, questions arise whether we are able to make this transition smoothly and effectively. There is discussion about the cost of the German Energiewende. E.ON announced the future split of their business into "green" and "traditional". There is concern about the supply security in Europe considering, e.g., Belgium winter 2014/2015, a partial solar eclipse over Europe on 20 March, 2015, a continuous fall in oil prices due to the shift to shale gas in the US, and the unrest in Ukraine at the border of the EU.

On the transmission level, more and more interconnectors are built, and new technologies like HVDC and SVC are employed. At the distribution level, smart grid solutions are developing rapidly empowering the prosumers and delivering voltage and frequency support, while EVs and storage technology are also showing promise.

The consequence of these developments is the creation of an increasingly complex power system. This fact combined with the effect of disruptive external events, including extreme weather, and our society's increased dependency on a reliable and uninterruptible electricity supply creates higher uncertainties on all levels.

This is where the challenge begins: how can we mitigate the increased uncertainties? One of the issues of reducing uncertainty is qualifying new technology and providing the evidence that the technology will function within specified limits with an acceptable level of confidence. A well-known method for de-risking a component, system or technology is validation or testing in a risk-free environment before installing it in the real world.

As the power delivery system develops from a "passive stable", predictable system to a complex "actively held stable" integrated system, we have to carry out a system verification process that not only includes component testing but also component and system interaction. An example here would be validation of advanced inverter functions. As more and more system parts are produced at different locations across the globe, the system integration and interface testing, i.e., interoperability, become even more important.

DERlab has identified this need for a shift towards system testing in power systems and addressed it in international workshops, conferences and events ever since. Although the challenge is huge, we will continue this effort in pre-standardisation.

International cooperation is crucial in solving multiple technical and regulatory problems to achieve a swift and smooth transition of the existing power system to the one that is fit for the future.

Peter Vaessen
Spokesperson of the DERlab Board
DNV GL

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Introduction

Integration of higher shares of distributed energy resources (DER) in saturated distribution grids implies the overcoming of technical limitations by the implementation of appropriate measures. The interaction between the transmission and distribution levels becomes more significant. Along with that, unpredictable risks for power system stability emerge in the context of system integration of new technology and little operational experience of working with new system components and their interoperability. Hence, the implementation of new technology poses new questions to system operators on the best way to control new equipment in order to guarantee appropriate power quality and reliability of supply.

"The identification of best practices and use cases for laboratory testing of systems and components in a system context is necessary in order to define future testing requirements."

Furthermore, the competitiveness of the electricity market forces equipment manufacturers to optimise system components design for minimal price. This constraint leads to lower margins in equipment parameters and usage of less or cheaper material. Failures in this case will mainly happen during abnormal situations or critical conditions in the power system. This 'design on the edge' can decrease the reliability of the equipment and thus impose a risk on the grids.

In this context, in order to develop reliable, efficient and safe smart grids of the future, we need to undertake the expected structural changes. New aspects, components and systems technologies have to be investigated in laboratory environments allowing real-scale tests and the testing of different smart grid configurations in different scenarios under safe boundary conditions without influencing the end customers of the electrical power supply system.

The identification of best practices and use cases for laboratory testing of systems and components in a system context is necessary in order to define future testing requirements. These use cases will also establish the basis for standards and grid codes in their formulation of requirements for grid integration of new technologies of DER.

DERlab currently cares for the abovementioned aspects as a project partner within a number of European projects and as an international network within the ISGAN / SIRFN framework.

In 2014 DERlab has reached an important milestone by becoming the Operating Agent of the Smart Grid International Research Facility Network (SIRFN, Annex 5 of the International Smart Grid Action Network), thus consolidating its position in international networking and scientific exchange of testing laboratories around the world.

The European Distributed Energy Resources Laboratories (in short DERlab) is the association of currently over thirty research institutes and companies conducting applied research in the field of Distributed Energy Resources (DER) and smart grids in Europe and the U.S. With various activities in research, networking and awareness rising, the association fosters the preconditions of pre-competitive and pre-normative research for a more environmentally sustainable power generation in the future. DERlab and its member institutes conduct and participate in research projects on DER devices and systems, with the special focus on optimisation of test procedures and on the development of research infrastructures.

Dr. Diana Mincu (Craciun)
Research Coordinator of DERlab

Photo: IRED 2014

International Networking and Knowledge Exchange

Building Blocks for Global Excellence

Russell Conklin on Challenges and Specifics of International Networking in Smart Grids*

* Russell Conklin is responding solely in his capacity as Vice Chair of the ISGAN Executive Committee. His views are his own and do not reflect those of the U.S. Department of Energy or the U.S. Government

Above and top right: Russell Conklin holding his presentation "A Global Network to Capture Global Experience on Smart Grids - The International Smart Grid Action Network" at the 6th International Conference on the Integration of DER (IRED 2014), Kyoto (JP)

Russell Conklin

- Vice Chair of the Executive Committee for the International Smart Grid Action Network (ISGAN), a Clean Energy Ministerial (CEM) initiative and IEA Implementing Agreement to accelerate the development and deployment of smarter electricity grids globally
- Policy analyst with the Office of International Climate Change Policy and Technology at the U.S. Department of Energy (DOE)
- Master of Public Policy degree from the University of Maryland, College Park
- Bachelor of Arts degree from the Pennsylvania State University

What are the prospects of international networking in the field of smart grids? How should the actors optimally liaise with each other?

Speaking on behalf of the International Smart Grid Action Network (ISGAN), I think the outlook is strong for continued and deepened international collaboration in the area of smart grids.

Electricity networks vary significantly from country to country, region to region in their technical characteristics, policy and regulatory frameworks, and institutional structures. The underlying drivers motivating adoption of new grid technologies and practices likewise vary. No two countries are exactly alike.

Yet, I've found that, consistently, countries around the world are asking the same questions about smart grids and grid modernisation. They want to know how to make their grids operate more reliably and efficiently. They want to identify strategies to better integrate newer generation technologies, like widespread distributed solar photovoltaics, and emerging end-use technologies, such as electric vehicles. Many developing and emerging economies are actively trying to extend cleaner, more reliable access to electricity to more and more of their people.

"As with all technological shifts, there will be big winners and big losers."

The answers to these questions cut across policy, regulation, technology, and institutional structures and raise the prospect that long-held business and operational models, and fundamental assumptions about how electricity networks are organised and managed, may no longer apply. The long-term investments needed are huge, with estimates in the hundreds of billions of dollars in the U.S. alone. And, as with all technological shifts, there will be big winners and big losers. That can be scary to a lot of grid stakeholders! Who pays? Who gets the benefits? Will my investment today be obsolete tomorrow?

Many organisations don't want to be a "first mover" on these changes. They want to be a "second-mover" or "third-mover" – in other words, to see an idea work first in someone else's market, state or country and only then try it out in their own area. As a result, there is a real hunger for hearing lessons learned and best practices, which is an area where international collaboration can provide real value. As I mentioned, no two countries' electricity systems are exactly alike. But working

Photo: IRED 2014

together, yes bilaterally, but also multilaterally through an effort like ISGAN, countries are able to broker connections across those specific areas of alignment, to share lessons learned from their own experiences, and hopefully to then replicate or adapt ideas with proven value, whether it's a business model, a technology configuration, a program design or even simply just a pilot project.

"I've had many, many conference calls scheduled at times when the folks in North America are just waking up and the people in Asia should already be home getting ready for bed. But they get on the phone despite this because they see value in the work."

International collaboration is always a bit of a challenge. Most people in this field, in smart grids, are very busy with their "day jobs", and international work is often an extra add-on. Yet, many folks are committed personally and professionally to the work they do internationally. They see the value and make that extra effort to support it, even if their "day jobs" keep them very busy. I've had many, many conference calls scheduled at times when the folks in North America are just waking up and the people in Asia should already be home getting ready for bed. But they get on the phone despite this because they see value in the work.

"You need to have some humility about what areas under the smart grid umbrella are truly ready for deep technical alignment."

So, I think the optimal way for those involved in international collaboration to work with each other is to take advantage of the gifts of the ICT revolution, i.e., to use webinars, online collaborative platforms, the "cloud," etc., complimented by phone calls, to implement much of the day-to-day cooperation and then use periodic face-to-face meetings to cover tougher issues or target specific challenges. Face-to-face meetings are important, because that is often where you build trust among international collaborators and have those side discussions that often uncover solutions to problems or new opportunities to make progress. But international travel is expensive, so face-to-face meetings shouldn't just be "talk shops", merely presenting information that could have been provided more easily in a webinar. They should be a real exchange of information targeted to solving real problems – putting the "work" back in workshop, if you will.

When working internationally, it's important to keep a couple of things in mind. First, countries, regions, even some subnational areas, often do not define terms the same way. In ISGAN, we gave up very quickly on developing a specific, global definition of smart grid; in many places, the local definition is defined by regulation or law. So, when having discussions internationally, you should make clear how you are defining the key terms, to ensure that, when Countries A and B are talking about a technology or a business model, they are actually talking about the same thing. Next, you need to have some humility about what areas under the smart grid umbrella are truly ready for deep technical alignment. The differences among countries are significant so, on some topics, it might not make sense to try to develop a single global model or tool that will be applicable everywhere. It might simply not be possible. Instead, the focus can be on good concepts or principles, for example, on project design that can be applied widely across countries and regions.

What is the most urgent problem that must be overcome through international collaboration before it is too late, and what are the possible ways to do so?

Not surprisingly, given my work with ISGAN and its Smart Grid International Research Facilities Network (SIRFN), I think that interoperability is an urgent area for attention. Sometimes, I worry personally that, with a push to quickly

ISGAN Executive Committee, March 2012

deploy technologies or revise a grid code or policy right away, some might be locking in suboptimal solutions that are not interoperable. This raises the prospect of technology obsolescence, higher costs, less competition among solutions (in areas where competition is appropriate), and so on. You could end up spending much more money trying to get two technologies to work together than you would if they had been truly interoperable in the first place. Someone ultimately pays for that – in many places, it's the electricity consumer. We're used to some level of this. For example, I carry around plug adapters when I'm traveling internationally so I am able to charge my phone no matter what country I'm in. I paid for them, and it's another thing to pack, but I'm used to it. But, with the scale of investments needed to modernise electric grids, make them cleaner, better engage consumers in their energy use, and so forth, this could be a major problem. No one wants to hear that the technology in which they invested today won't work tomorrow.

"The work we are doing under SIRFN on the test protocols for advanced PV inverter functions is a great example of how countries can work together to address key areas of need"

"Utilities are undergoing an evolution, from seeing electricity consumers as just rate payers to seeing them as customers: consumers are the heart of the grid"

Interoperability, like much of smart grid, cuts across policy, technology, regulation and, of course, standards, so I think a combination of sharing lessons learned from actual experience as well as sustained technical engagement on the foundations of interoperability, be it standards, testing protocols, or whatever, is a good mix for international work.

What would you say is a good example of successful international cooperation in interoperability and smart grids?

I think the early days of the Smart Grid Interoperability Panel (SGIP), coordinated back then by the (U.S.) National Institute for Standards and Technology (NIST) provides great examples of successful international cooperation. SGIP was stood up, in part, to help identify the key standards for an interoperable smart grid and to coordinate a response to gaps in areas that did not have appropriate standards. Most of the major international standards development organisations (SDOs) took part in SGIP, as did many multinational companies, several foreign governments, and other international stakeholders. NIST also helped connect SGIP with, at least, the core interoperability discussions in Europe and several key countries in Asia. I recall that the idea was for everyone to lay out how they were thinking about interoperability and what were their priority areas for attention, and then to identify opportunities for joint work or better alignment.

Closer to home, I think the work we are doing under SIRFN on the test protocols for advanced PV inverter functions is a great example of how countries can work together to address key areas of need – in this case, test protocols to assess inverter performance of advanced grid functions, building on the IEC 68150-90-7 definitions – while recognising significant national differences in grid configurations and practice.

In this respect, how do you see the role of SIRFN and the DERlab activities within it?

I see the role of SIRFN, and the DERlab activities within SIRFN, as providing the building blocks for global excellence in interoperability testing practice. Whether its addressing a specific challenge, such as the need for validated test protocols to assess advanced smart inverter functions, building international capacity on more novel testing methods, like co-simulation and controller hardware in the loop, or improving knowledge on the emerging characteristics integrated power systems testing, SIRFN brings together many of the world's

IRED 2014

leading facilities and leading experts to advance the state of the art in this critical field. We are not a SDO, a certification body or an organisation responsible for adopting grid codes. But we can provide the building blocks that make the work they do easier, or faster, and hopefully better, for the benefit of all.

How can successful international networking influence consumer awareness and engagement and why should it be in everyone's interest?

Consumers pay for the grid; they use the electricity; and, with distributed generation, they are beginning to become energy producers too (i.e., the so-called "prosumer" that produces and consumes electricity). Around the world, utilities are undergoing an evolution, from seeing electricity consumers as just rate payers to seeing them as customers, in the same way that a consumer electronics or a car company sees them. This has already happened in some markets; it's just beginning in others. But the switch in thinking reflects what has probably been true all along to some extent: consumers are the heart of the grid. We now expect consumers to take a much more active role in the grids development and operation, for example, through demand response measures that help balance variable renewable generation. To what extent this will be conscious participation on the part of a consumer rather than automated "set and forget" configurations is not clear and will likely vary from market to market. But, consumers will increasingly expect reliable, cost-efficient and high-quality energy services from their utilities and service providers, in much the same way that cellphone users now expect a variety of services from their telecom companies.

The critical role of the consumer is a key reason that ISGAN has focused on excellence in consumer engagement and empowerment for its inaugural Award of Excellence competition. International knowledge sharing and networking can identify good practices in consumer engagement and support the replication of proven ideas in other markets. It can also raise the profile of this issue for grid decision makers, through reports, workshops, and similar. In addition, the knowledge shared through international networks, like ISGAN and its partner, the private-sector Global Smart Grid Federation, can help inform the development of educational materials targeted to the specific needs of a particular country or region.

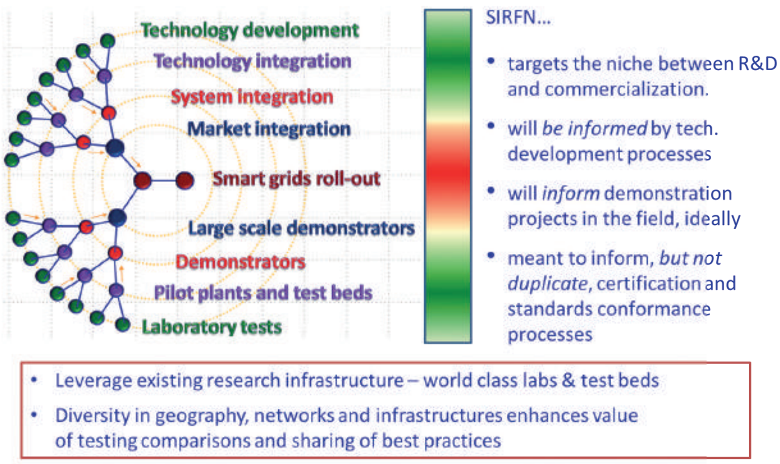
I appreciate the opportunity to participate in this interview and the DERlab Activity Report. I view the collaboration with DERlab through SIRFN to be very valuable and, therefore, wish to thank all those that made it possible, including the EC Directorate General for Research and Technological Development (DG RTD), DG Energy, the ELECTRA IRP project, the German government, and, of course, the DERlab office.

Russell Conklin

DERlab Establishing Collaborative Testing and Evaluation Capabilities as SIRFN Operating Agent

A key to advancing the deployment of a smarter electric grid is the development of technologies, protocols, standards, and systems that can function effectively in a variety of geographies and grid environments. To support this development, the Smart Grid International Research Facility Network (SIRFN) provides a coordinated network of smart grid research and test-bed facilities and relevant demonstration projects among countries participating in the Implementing Agreement for a Co-operative Programme on Smart Grids (ISGAN). The establishment of strong collaborative testing and evaluation capabilities that can be leveraged by the international community and, in particular, ISGAN participants can be a central enabler to the design and implementation of smart grids.

SIRFN focuses on information sharing and project development for six technical topics: Renewable Energy (RE) and Distributed Energy Resources (DER) Integration; Microgrids; Building Automation; Distribution Automation; Plug-in Electric Vehicle Integration; and Cybersecurity. In practice, work will not proceed at the same pace on all six topics, and the next revision to the SIRFN work plan will focus on a small subset of topics that are active or being actively planned. SIRFN participants are open to consider other topics if opportunities arise.

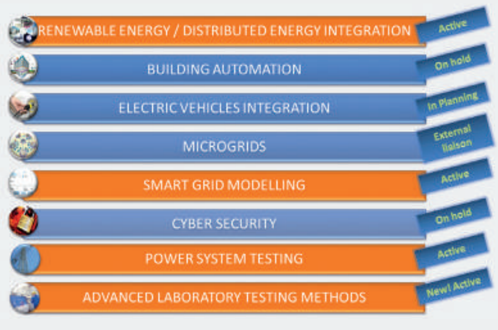


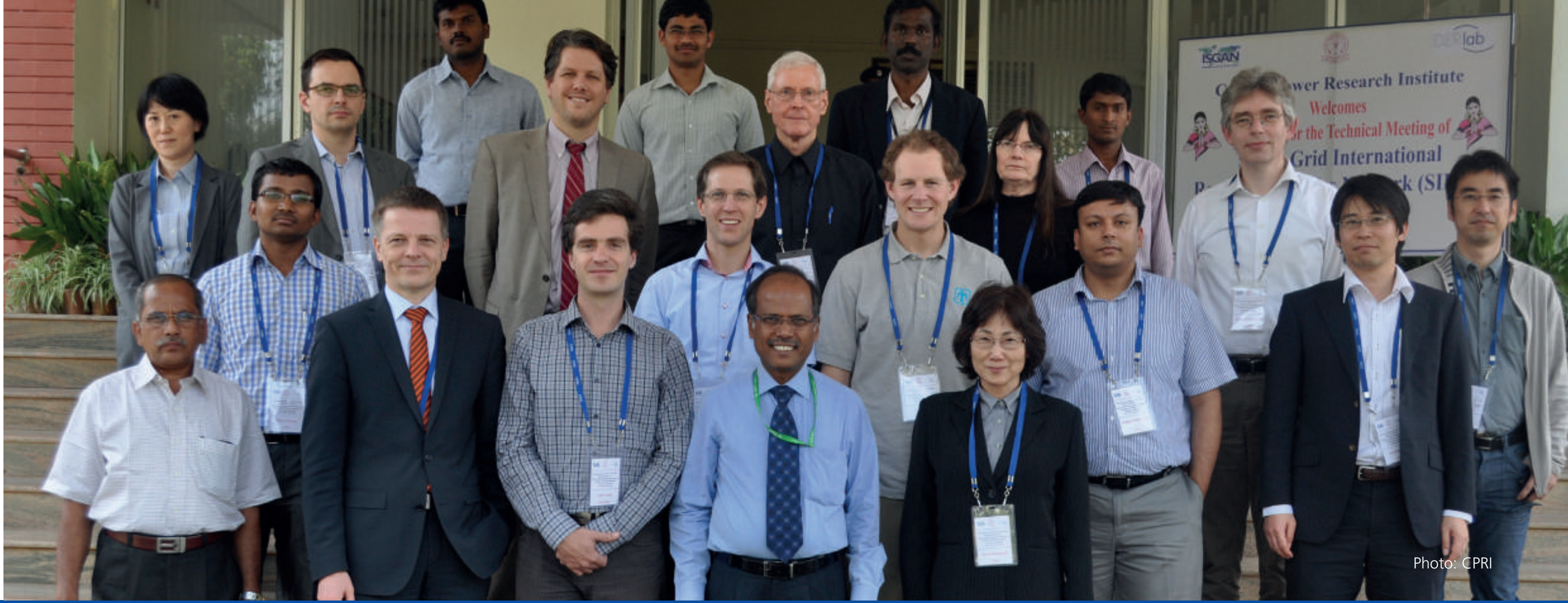
Info

SIRFN

SIRFN builds a framework for proposing, selecting and implementing projects that matches the needed evaluation with testing capacities and shares non-proprietary results for the improvement of smart grid technologies, protocols, and standards. SIRFN gives participating countries the ability to evaluate jointly selected pre-competitive technologies, protocols and systems in a wide range of smart grid implementation use cases and geographies using common testing procedures.

Research and test-bed facilities participate in SIRFN based on their complementary capabilities to conduct specialised, controlled laboratory evaluations of integrated smart grid technologies and protocols in areas such as distributed and renewable energy integration, energy storage systems, advanced distribution management, advanced metering infrastructure, cyber security, and similar applications. In this way, research within each individual member country will derive the value of the unique capabilities and environments of the other partner nations. Data from testing activities will be made available to all SIRFN participants to accelerate the development of smart grid technologies, protocols, standards and systems, as well as enabling policies.





As of 2014 DERlab carries the role of the Operating Agent of SIRFN caring for the following aspects:

- Leading Annex Task planning and scheduling, compilation of inputs from Task/Subtask leads into deliverables
- Task coordination, scheduling, and communications (in cooperation with Task Leaders)
- Assisting Task Leaders and Subtask/Activity Leaders as necessary
- Preparing and summarising Annex-related calls, meetings and workshops
- Reporting to the ISGAN ExCo (periodic status reports, presentations)
- Facilitate publication of reports, tools, and other materials, in coordination with other Annexes as appropriate
- Preparing and delivering requests to the ISGAN Secretariat, including for use of the ISGAN common fund, when needed and appropriate
- Development and implementation of an Annex quality assurance policy in accordance with any ISGAN-wide quality assurance plan
- Annex-level dissemination and implementation of any direction or requests received from the ISGAN Secretariat or Executive Committee

In the framework of SIRFN, DERlab organised one workshop and two webinars on the topic of Power System Testing.

On 17 November, 2014, DERlab organised a side event at the IRED 2014 conference in Kyoto, Japan, under the title "ISGAN Smart Grid International Research Facilities Network (SIRFN) Technical Meeting" as a SIRFN biannual meeting. SIRFN laboratories have discussed current and future cross-lab research projects including advanced DER interoperability testing, smart grid modelling, and power system component testing.

Another two workshops on Power System Testing and Advance Laboratory Testing were held at the premises of EDF in Fontainebleau (FR) on 19 March, 2015, as side events at the DERlab General Assembly.

Top and above: Participants of the SIRFN Technical Meeting in Bangalore (IN) hosted by the Central Power Research Institute (CPRI) in March 2014

Below: SIRFN Technical Meeting as a side event attached to the IRED 2014 in Kyoto (JP), November 2014

Joint DERlab/SIRFN pre-standardisation activities:

Towards standardised procedures for advanced DER power converter interoperability tests

Jay Johnson (Sandia National Laboratories, Albuquerque, NM, USA)
Roland Bründlinger (AIT Austrian Institute of Technology, Vienna, Austria)
Ricardo Alonso-Segade (TECNALIA, Derio, Spain)

DERlab members develop unified procedures for the validation of advanced DER power converters

Latest state-of-the-art power converters used in Distributed Energy Resources (DERs) can provide a wide range of advanced functions, supporting the electric grid through commanded and autonomous operating modes. These functions have been standardised in the International Electrotechnical Commission (IEC) Technical Report 61850-90-7 [1] in 2013. However, there are still large gaps with respect to the test procedures and certification standards for verifying the interoperability and functionality of the advanced DER functions. Sandia National Laboratories (SNL), the Austrian Institute of Technology (AIT), and TECNALIA – as part of a collaboration through the DERlab-operated Smart Grid International Research Facility Network (SIRFN) – are designing and exercising test protocols to characterise the interoperability and advanced functionality of these devices.

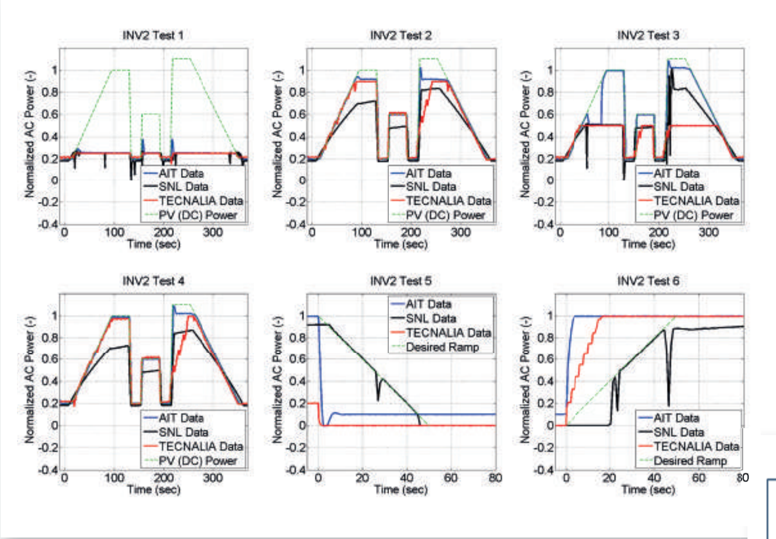
IEA-ISGAN smart grid collaboration and SIRFN projects

New interoperability requirements demand adequate testing and certification standards

Driven by new requirements in Europe [2] and proposed changes in California [3], PV inverter, power conditioning system (PCS), and other distributed energy resources (DER) manufacturers are incrementally adding advanced functionality to their devices. Large DER devices will likely be monitored and controlled with dedicated supervisory control and data acquisition (SCADA) controllers, while for large quantities of small DER devices, an aggregator, gateway, or translator will most likely act as an intermediary between the utility and DER [4].

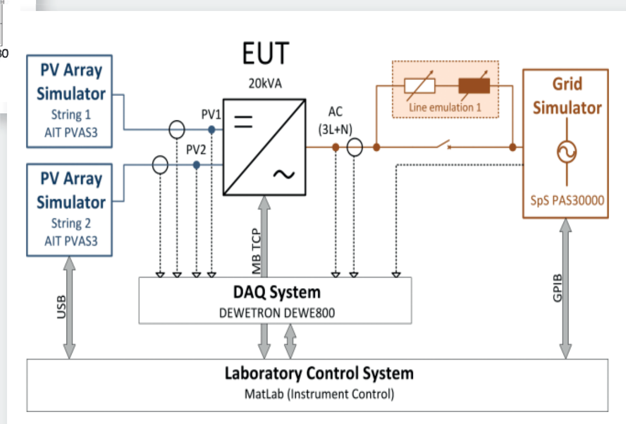
DERlab members Sandia National Laboratories (SNL), Austrian Institute of Technology (AIT), and TECNALIA created advanced interoperability test beds and completed an initial set of experiments [5] using the first version of the Sandia Test Protocols [6], [7]. In order to quickly test the large number of functions and parameter sets in the Sandia Test Protocols, SIRFN laboratories are automating the testing process, enabling the efficient yet comprehensive validation of the compliance with the standards requirements.

Ultimately, the SIRFN group aims at providing experimentally-validated recommendations to establish and harmonise certification procedures from IEC [9], UL [8], IEEE, and other standards-making bodies. With conformance test procedures and associated certification schemes, grid operators can rely on the coordinated and stable performance of advanced interoperability functionalities, and manufacturers can list their products to gain access to multiple markets.

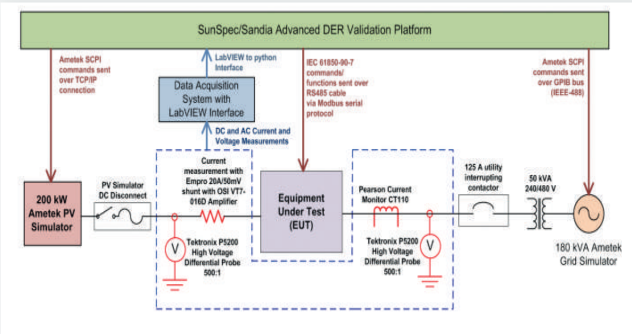


These standardised DER capabilities provide the basis for the full integration of PV and battery systems into future smart grid control schemes. Eventually this allows the utility and grid operators to manage a large number of PV systems in a unified way and capture the potential benefits of inverter-based DER.

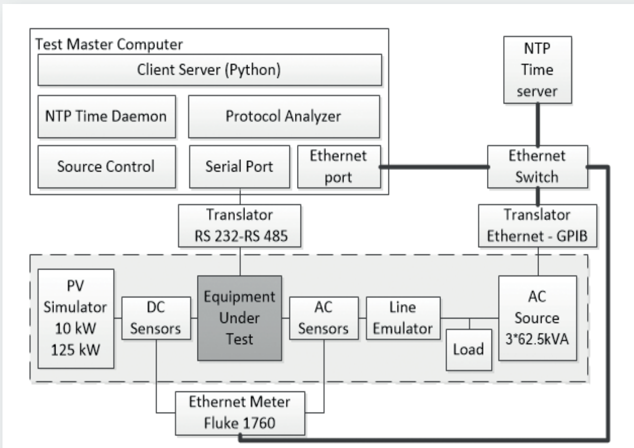
Left: Exemplary results of active power control tests at AIT, SNL and TECNALIA [5]



Advanced interoperability test setup at AIT



Advanced interoperability test setup at SNL



Advanced interoperability test setup at TECNALIA

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Standardisation Recommendations by STARGRID

With the advent of smart grids, the development and adoption of standards ensuring interoperability and security becomes imperative to the field of electricity networks. In the past two years, STARGRID has closely followed the various standardisation activities and cooperated with involved stakeholders from all parts of the smart grid value chain, to work out the most crucial requirements pertaining to smart grid standardisation and regulation in the near and medium term. These project activities result in a set of recommendations, addressed not only to standardisation bodies and regulators but also to smart grid industries and operators.

Photo: Mihai Calin, DERlab

Info

STARGRID: STandard Analysis supporting smart eneRgy GRID development
Duration: October 2012 – January 2015
Funding: The Seventh Framework Programme of the EC
Partners: five partners, including DERlab

For further information and the project outcomes please visit:
www.stargrid.eu

STARGRID Concluded with Recommendations for Smart Grid Standardisation Framework

The final project workshop "Standards Hub for Smart Grid Industries: Recommendations for the Standardisation Framework" held in Brussels (BE) on 23 January, 2015, brought together promoters and stakeholders of various European smart grid initiatives, standardisation bodies and regulators to discuss the STARGRID recommendations on smart grid standardisation and regulation. Particular topics included:

- Relationship between regulation and standardisation: current approach and possible modifications
- Internationalisation vs. national/local solutions
- Market freedom vs. strict regulation
- Impact on industry and users
- Next necessary steps
- Lack of standards or lack of knowledge: how to increase the outreach of standardisation?

The workshop also presented additional STARGRID outcomes, including the development of a standards database, the results of an industry survey and the stakeholders' requirements analysis.

The final outcome of the project consists of six recommendations (presented below) regarding the standardisation process addressed to policy makers, regulation authorities (EU and national), industry and standardisation bodies.


Photo: Mihai Calin, DERlab

STARGRID final event in Brussels (BE), 23 January, 2014

Enrich an Obligate Core with Modular Elements Fitting National/Local Regulation

addressed to: regulation authorities, standardisation bodies

Main Recommendations

1. Set up a collaboration framework between regulation authorities and standardisation bodies, in particular at the national level. National technical regulation should be based on international standards wherever possible.

2. Provide a core of smart grid regulations and standardisation for the following core applications:

• System Interfaces (see **Recommendation 2. Systems and regulation for system interfaces**)
• Security and Privacy (see **Recommendation 4. Increase security and privacy**)
• DER-Grid Connection Rules (see **Recommendation 6. Harmonise the regulation and standardisation framework for DER interconnection rules**)

While many of today's smart grid actors are heavily regulated, like grid operators, the uptake of distributed energy resources (DER) and the coupling between information networks and electricity grids means that new opportunities open up for real market-based energy services, including, for instance, aggregation of DERs in a virtual power plant or new energy services for end customers based on modern monitoring capabilities. The interaction between regulated actors and free market raises new challenges: it can be a big problem for energy service companies if they require access to their customers' meter data, but each metering operator uses their own data format and different procedures for data transmission. Similarly, if grid operators, even within one country, require different interfaces for DER control, this leads to high costs and prevents the development of innovative add-on solutions.

It is unlikely that standardisation alone will be able to solve this problem. Standardisation is useful for harmonising technical solutions between different market actors since they all may expect to profit from an improved market development due to harmonisation. Fully regulated actors, on the other hand, have little incentives to engage in the harmonisation of their interfaces. It is therefore essential that at least the national regulator enforces common interfaces, wherever interaction between regulated actors and market actors takes place.

This implies that regulators must become active in a field that has so far belonged to the realm of standardisation, namely the provision of technical specifications for certain interfaces. On the other hand, international standardisation organisations, like the International Electrotechnical Commission (IEC), may have already developed solutions for these interfaces, and it is absolutely mandatory to make use of this work. However, there is more work to be carried out. International standards tend to be very generic and require additional profiling before standards can actually be applied to specific use cases [1]. This remains a task of the regulators. On the other hand, it would make sense for them to delegate this task to a national standardisation committee, since the standardisation bodies already have a process in place for the participation of the affected actors, and many competences are available in the committees. For this purpose, a mandate could be issued by the regulator to the standardisation body, which would set up a special committee dedicated to the development of the profile.

Examples:

Grid Codes & Smart Metering

The development process of European grid codes by the Agency for the Cooperation of Energy Regulators (ACER) is largely in line with this recommendation. The grid codes specifiy many functional requirements but leave the specification details to national implementations. For the actual code elaboration, ACER has issued a mandate to ENTSO-E, the association of European TSOs.
A similar case can be made for smart metering: two directives of the European Commission demand the member states to implement measures for a smart meter rollout by 2020. The directives ask for measures to ensure interoperability and prescribe certain functional requirements but do not explicitly insist on harmonised interface specifications. This topic is also addressed in **Recommendation 2. Standards and regulation**.

There is a necessary trade-off between free market development and strict regulation. Regulation in one area may foster market development in other areas by removing blockers and ensuring equal opportunities for all involved actors. On the other hand, regulation can slow down innovation, especially if it imposes a particular technical solution, as proposed for system interfaces. A possible way to diminish this risk is to allow alternative solutions alongside the mandatory proposition: regulated actors will be enforced to provide a particular common interface but may offer alternatives.

The (temporary) diversity of standards and regulations in Europe may be seen as an opportunity. Regulatory conditions regarding smart grids are and will most likely remain diverse within the next few years among member states of the EU, and the development of necessary rules should not be hampered too much by the tedious search for a commonly acceptable compromise. It therefore makes sense in certain domains to impose a common European framework, which must then be cast into specific national implementations by the relevant regulators. At the same time, the specifications should not be too fragmented, to reduce inefficiencies resulting from the variation. For this reason, at least member states should be required to adopt binding rules for certain applications (in particular system interfaces involving regulated actors, security and data protection, and interconnection rules for distributed energy resources).

Implementation

This recommendation is addressed mainly to politicians and regulators, but it also affects standardisation bodies. A stronger collaboration between standardisation organisations and regulators is considered crucial by the authors to enable markets for core smart grid functions. In particular, national technical regulations should be based on international standards if possible, which in its turn requires available or developed standards to cover relevant use cases [1].

addressed to: policy makers, regulation authorities (EU and national), standardisation bodies

Standards and Regulation for System Interfaces

Main Recommendation

Interoperability on system interfaces should be ensured by standardisation and regulation. For this purpose, regulation authorities shall define obligatory specifications that are uniform at least at the national level. Voluntary standards complement the framework by specifying the system interfaces between market actors.

Corollary Recommendations

- Implement a European framework that specifies a set of system interfaces requiring national regulatory provisions, to ensure interoperability at least on a national level. Foster voluntary cooperation between member states to develop harmonised solutions, without slowing down the process excessively.

- Technical specifications imposed by regulatory means should be based on international standards, wherever possible, and must define test procedures and certification requirements (see **Recommendation 3. Prioritise interoperability test specifications in smart grid standards**).

- Take security seriously: standardised solutions require a high level of security measures, to prevent devastating effects of large scale attacks.

- System interfaces beyond the realm of regulation should be addressed by standardisation committees or other dedicated stakeholder working groups.

One of the main barriers for the market introduction of smart grid technologies involving distributed energy resources and end customers in general is the lack of standardised interfaces between smart grid stakeholders. The legal and regulatory conditions in many cases are flexible for business cases involving several stakeholders such as energy traders, energy service companies, operators of flexible load and generation, smart meter owners, etc. (even though market conditions do not necessarily provide sufficient incentives at the moment). In contrast to this, the lack of clearly defined interfaces between the relevant systems can significantly restrict the development of new smart grid based services.

Although, to a great extent standards covering the system interfaces are available or are in preparation. They do not immediately guarantee interoperability due to the choices to be made (profiling) and the overlapping scope of different standards. In order to overcome this problem, we recommend a regulation be put in place enforcing the specification of the relevant system interfaces where interfaces to regulated actors are concerned. Interfaces covered by regulation should be uniform at least within each member state (as explained in Recommendation 1, national uniformity is considered a realistic short-term perspective compared to European-wide common system interfaces).

In order to allow for full interoperability, system interfaces should also be specified in a more extensive way than other communications: they need specifications regarding authentication, access permissions, and data models. Regulatory provisions should be publicly and freely available, and they must include rules for testing as well as for certification.

System interfaces

A possible list of system interfaces is as follows (excluding interfaces that are already well specified, like grid-grid communication), see also Figure 1:

1) Grid operator – local controller (regulated)

2) Metering interfaces: (regulated)

a. SMG – local controller
b. SMG – authorised external entity
c. Metering operator – other authorised external entity

3) Authorised external market entity – local controller (unregulated)

SMG is the Smart Meter Gateway, which provides the Local Network Access Point (LNAP). A local controller could be a DER controller, a Customer Energy Management System (CEMS), a charging controller or the like. The local controller may also be integrated into the Smart Meter Gateway.

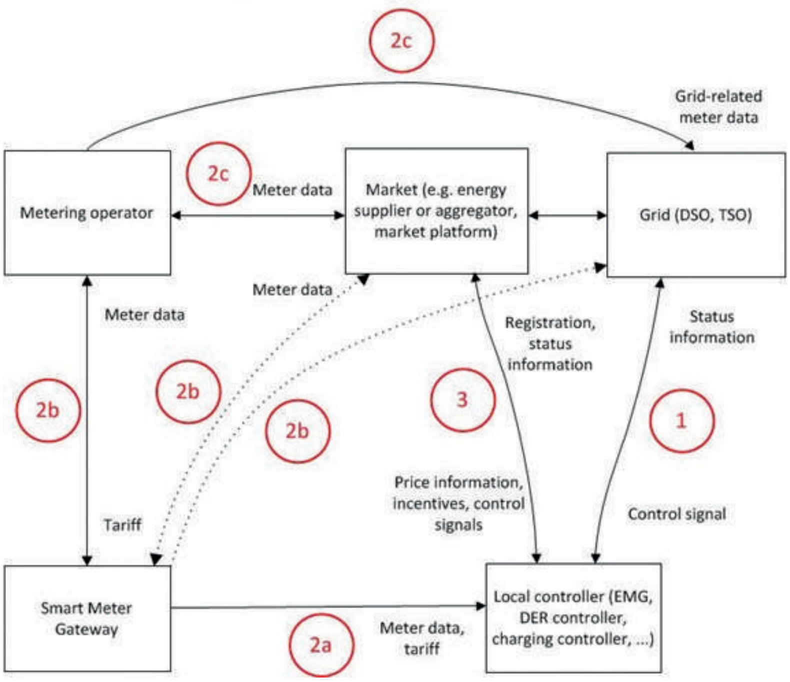


Figure 1: Proposed system interfaces

Good practice 1: Smart Metering

Germany and Great Britain are in the process of issuing a clear regulation for smart metering [2], prescribing, among others, security and data protection measures, as well as the data format for message exchanges. The latter is based on the COSEM data model, defined in IEC 62056, in both cases. The frameworks explicitly take into account services beyond metering itself, such as remote load control, or data access for service providers other than the metering operator.

Expected Impact

- Secured interoperability
- Increased market competition due to standardised interfaces; commercial feasibility of innovative energy services; accelerated market development due to reduced connection costs
- Reduced risk of vendor lock-in for grid operators, DER operators, etc.
- Increased end customer participation in energy markets; demand response implementations
- Competition for the best communication solution cut-off

Implementation

This recommendation is addressed to legislation and standardisation bodies. They should aim to establish regulations/standards suitable to ensure interoperability. The technical specifications should be based on international standards, and the development process of the regulations may include a cooperation between regulators and (national) standardisation bodies, as proposed in **Recommendation 1. Enrich an obligate core with modular elements fitting national/local regulation**. Harmonised European specifications are desirable, and a process involving the definition of system interfaces and basic requirements at the EU level could initiate the national legislatory processes. Cooperation of member states and the use of international standards should be encouraged.

addressed to: standardisation bodies, industry

Prioritise Interoperability Test Specifications in Smart Grid Standards

Main Recommendation

Prioritise the development and adoption of interoperability test specifications to validate interoperability of components and systems for smart grid applications.

Corollary Recommendations

• Identify and define critical use cases where interoperability tests are most urgent. Whenever necessary for these critical situations, develop missing use cases.
• Organise a coordinating entity to establish and maintain a certification system for the interoperability of smart grid devices and systems and to define what use cases should be covered by such a certification system.
• Develop a process to increase the involvement of testing and certification organisations in the standardisation process, in particular regarding the development of test specifications.
• Foster cooperation between stakeholders of the smart grid value chain (especially energy and communication operators) to develop smart grid solutions based on standardised approaches to enhance the interoperability of components and systems (e.g., user groups for specific standards).
• Support the coordinating activities of the SGCG concerning the identification of critical use cases and the development of methods and tools for the implementation of interoperability tests.
• Take advantage of EU funded projects to develop interoperability tests specifications. Specific networking actions should be addressed by targeted calls (e.g., within H2020).
• In the elaboration/revision process of smart grid standards, include the verification that interoperability testing provisions are covered.

Interoperability overview and requirements

Interoperability represents the ability of system/subsystem/intelligent devices to exchange information and use it in order to perform required functions. The risk of non-interoperability increases with the complexity of the system. Moreover, the smart grid shall be interoperable with related infrastructures (e.g., intelligent transport, smart cities, etc.) in order to sustain the development of the energy market.

Interoperability not only concerns communication and energy operation aspects but has a broader impact across related sectors: organisation, regulation, market, social sector, etc. Standardisation plays a crucial role in achieving interoperability goals, provided that it may ensure total internal consistency, robustness and efficiency.

Standard conformance is a prerequisite for interoperability, and, thus, it is necessary, but it is not a sufficient condition to guarantee the system interoperability: standards often cover a broad range of use cases so that a specific profile needs to be developed for each implementation.

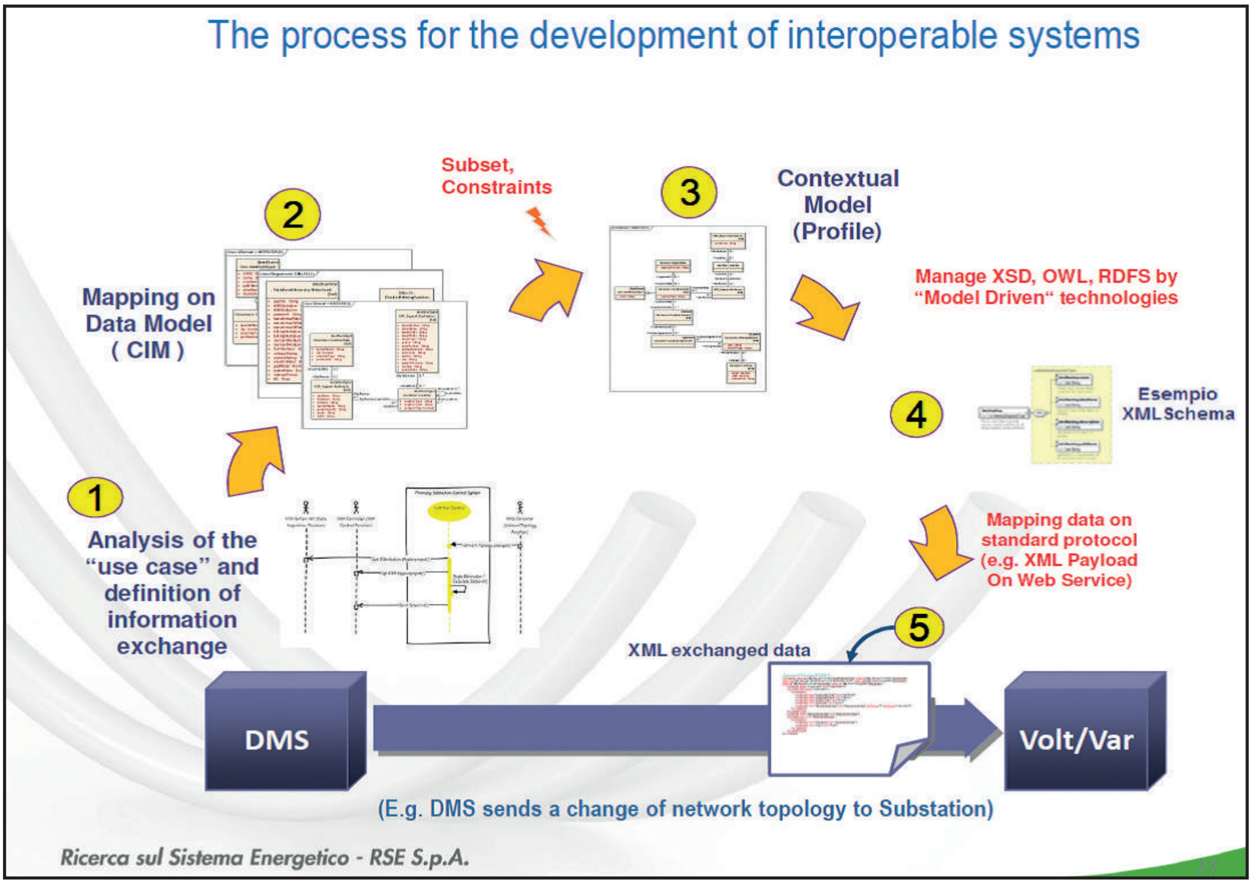
Therefore, in order to demonstrate the interoperability of any equipment/device integrated in the smart grid, specific interoperability tests are necessary. The use cases related to an application define the information exchange between systems at an abstract level. The mapping of this information on ICT standards, both at the information and communication levels, defines a set of rules that should be checked through interoperability tests.

To guarantee the repeatability and reproducibility, interoperability test methods have to be developed, agreed and standardised.

Use cases selection

Besides the dedicated standards user groups, which perform the actual development of the detailed use case and testing specifications, a coordinating entity would be of great benefit. It could define basic criteria for the selection of use cases, refine the methodology, maintain an overview of available testing specifications, and develop a roadmap for the development work, in close interaction with the affected stakeholders.

Where regulatory provisions are concerned, the task of defining the use cases is in the regulator's responsibility. It can make sense to delegate the task to a user group or an industry association by issuing a formal mandate. The interoperability tool proposed by the WGI Group of the SGCG is a helpful instrument to this analysis, also from a methodological point of view. The participation of testing/certification organisations in this process would be important.



Data models

Since a smart grid may incorporate many different types of physical networks, interoperability specifications should not restrict the choice of physical communication layer. Instead, interoperability must be ensured mainly in the upper communication layers, like the data model. For the smart grid there are three relevant data models. The so called Common Information Model (CIM) covers the "Operation", "Enterprise", and "Market" zones, whereas the other two reference data models covering "Process", "Field" and "Station" zones are IEC 61850 (for "Generation", "Transmission", "Distribution" and "DER" domains) and COSEM (for smart metering: "DER" and "Customer premises" domains). Harmonisation of the three data models is paramount.

Profiling process

The concept of a profiling process, in order to specify in a defined context which standards (parts) have to be used and how, represents a suitable tool to achieve interoperability between systems.

The concepts of "Basic Application Profile (BAP)" and "Basic Application Interoperability Profile" (BAIOP) (e.g., a profile for the interlock function), recommended by the Working Group Interoperability of the SGCG, are aimed at the profiling process. Groups of BAPs and BAIOPs provide functionality at a higher level. Granularity of profiles and guidelines for the definition of BAPs and for their generation are deemed urgent matters of discussion.

Interoperability Certification System

A mutually acknowledged certification system for interoperability testing should be implemented with the twofold aim of:

• certifying the interoperability performances of devices and systems against the developed specifications, possibly leading to the appointment of an interoperability label

• accrediting certification laboratories conforming to agreed interoperability certification procedures

A mutually acknowledged certification system ensures that interoperability tests performed in different countries and by different laboratories against the same use cases and profiles and procedures will produce the same results. This could prove to be of great commercial value for equipment and system producers.

EU funded projects

EU funded projects could be a suitable context to validate interoperability tests specifications against large-scale use cases. Good reference examples are, for instance, the projects SmartC2Net and COTEVOS. They could possibly also target the actual development of specifications, ensuring the due consideration of interoperability aspects already starting from the concept phase (interoperability by design).

The system interoperability approach developed by means of EU funded projects with the stakeholders on board is most economical and effective if it can produce standard solutions at the EU level.

Expected Impact

The cost of executing interoperability tests might increase the costs for equipment and system providers. However, the interoperability certification may constitute a quality label, which could facilitate the procurement phases and the value for money of the validated products. The release of a quality label from the interoperability certification has been employed for years in sectors other than energy, for instance, in telecommunication [3]. In the end, this may reduce cost for technology integration, and the interoperability validation is expected to ensure the security of supply by the network operators, reduce their vendor dependence, and is expected to lead to lower costs at the system level.
Interoperability tests validate the use case step by step: this allows, among others, to validate early implementation of standardised technologies and to provide feedback to standardisation bodies for the validation of the standards themselves.

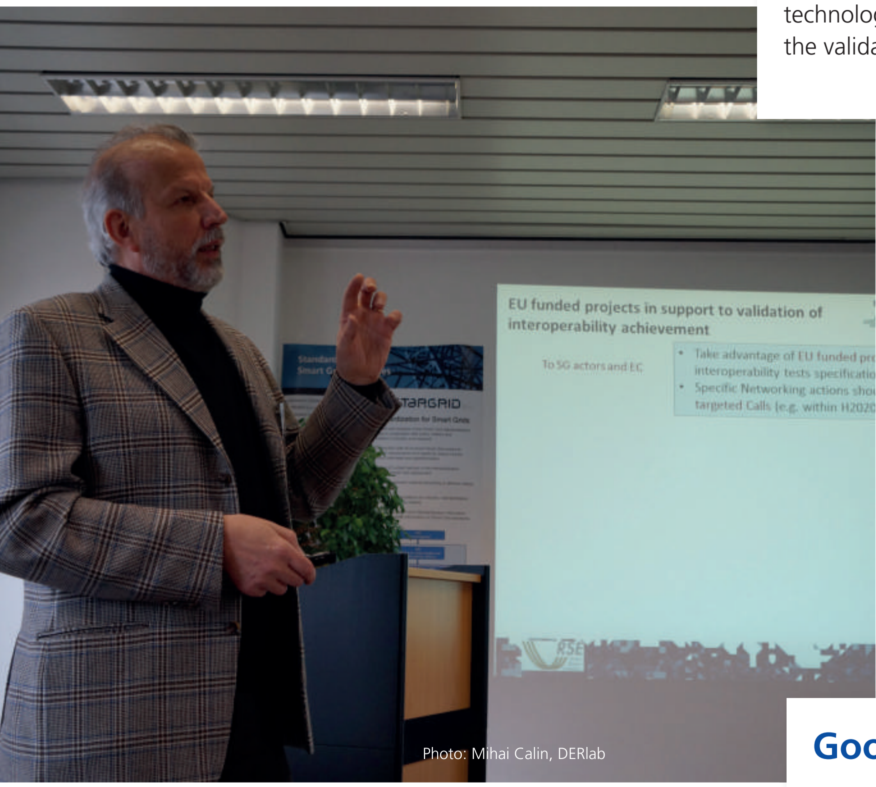


Photo: Mihai Calin, DERlab

STARGRID final event in Brussels (BE), 23 January, 2014

Main Impacted Stakeholders

Smart grid stakeholders will only invest into fully interoperable systems. They have the task to identify and define critical use cases for interoperability tests.
ICT providers and telecom operators should contribute to define the proper conditions (protocols and data exchange models) for the interoperability validation.
Equipment manufacturers and system integrators would initially cover the costs of requirements for interoperability tests, and this will affect their competitiveness.

Good Practice 2:

Take advantage from EU funded projects to develop interoperability tests use cases and specifications.
A good reference is the use case of "Voltage Control in Medium Voltage Grid" developed within the project SmartC2Net.
See also the EU-FP7 Project COTEVOS (Concepts, capacities and Methods for Testing EV Systems and their Interoperability within the Smart Grids) on www.cotevos.eu.

Implementation

The basis of the implementation of the interoperability tests is the definition of the use cases. This is especially a task of smart grids stakeholders in their specific context, in cooperation with ICT and telecommunication operators. This first step is already partly in progress within the activities of the SGCG. A first definition of generic high level use cases is already available [4].
Standardisation bodies need to implement a suitable process for the development of testing and certification specifications, involving coordination with the relevant user groups and laboratories. The direct participation of SMEs and sector associations is strongly recommended, for the sake of transparency and to supervise such aspects as cost-benefit issues.

Increase Security and Privacy

addressed to:
policy makers,
regulation authorities
(EU and national)

Main Recommendation

Develop a standards framework for security against physical and information attacks and data protection encompassing smart grids requirements with a coordinated and systemic approach. The latest report produced by SGIS group can be a good supporting reference for this goal.

A smart grid is intrinsically a system which can be highly sensitive to information security problems. The overall operation of the electric/energy infrastructure, with its strict dependence on the interaction with communication infrastructures (in many cases involving public networks), exposes the entire system to risks of malicious attacks (physical and cyber). Moreover, the required availability, the complexity of the entire system and the huge number of different players and deployed technologies (e.g., the monitoring network) dramatically increase the number of vulnerabilities that can be exploited. Security must be taken into account to ensure adequate operation of the smart grid and also for consumer confidence (for example, data privacy of smart meters was identified as a critical issue during the STARGRID assessment).

Consumer privacy cannot be sacrificed when exploiting the benefits of the smart grid. Smart meters and smart appliances will provoke a rapid increase of private data online (consumer behaviour and characteristics), and it is not clear who will have access to this information in addition to the utility without the consent of the customer.

No consensus currently exists on the privacy implications inherent within the grid, and there is a lack of standards and procedures to deal with this issue. Translation of legal concepts on personal data protection into technical requirements needs further support by the appropriate standards. Comprehensive definitions of personally identifiable information and execution of privacy impact assessments (PIAs) will become crucial in the utility industry.

Traditional security solutions may be ineffective against the attacks aimed at the smart grid operation and information system. A new scheme needs to be developed based on the anti-intrusion rules.

Security is a global issue, requesting an overall approach to face new vulnerabilities and risks (e.g., use of a public network instead of a private and segregated one, physical security of smart meters). Again, the certification process is paramount. Certification is not enough per se: security aspects should be considered already in the smart grid conceptualisation and the design phase, according to the security-by-design concept.

Corollary Recommendations

- Stakeholders should clarify and agree on the requirements on information security and data privacy. Cooperation of the operators of the involved networks is essential to this extent.
- Stakeholders should use standardised formats, language and models for the specification of requirements on security/privacy.
- Approach the security standardisation through the security-by-design concept based on a thorough use case definition and associated risk analysis. Standardise the approach methodology.
- Take advantage of EU funded projects to develop security use cases and specifications.
- Coordinate security and interoperability analysis approaches.
- Develop a harmonised legal framework across Europe, ensuring security of the energy system and the protection of the data.
- Collect the minimum amount of personal information needed without compromising the quality of the provided services. Anonymise individual identity.
- Transparency: inform the customer about the collection, use and disclosure of personal details and accept their preferences. Always obtain express consent before disclosing personal information to third parties. Allow consumers to access their personal data and make corrections.
- Enhance awareness and provide clear instructions on information privacy and protection to utilities and consumers using smart grid services. Policies at the EU and country level should be implemented to overcome cultural barriers to privacy and data protection.

Good Practice 3:

Take advantage from EU funded projects to develop security use cases and specifications.
The project SoES (www.soes-project.eu) has developed reference security analyses for fundamental use cases: “Voltage Control in Medium Voltage Grid”, “Photovoltaic Storage and Generation”, “Load reduction programs”, and “Smart Meter Configuration”.

Implementation

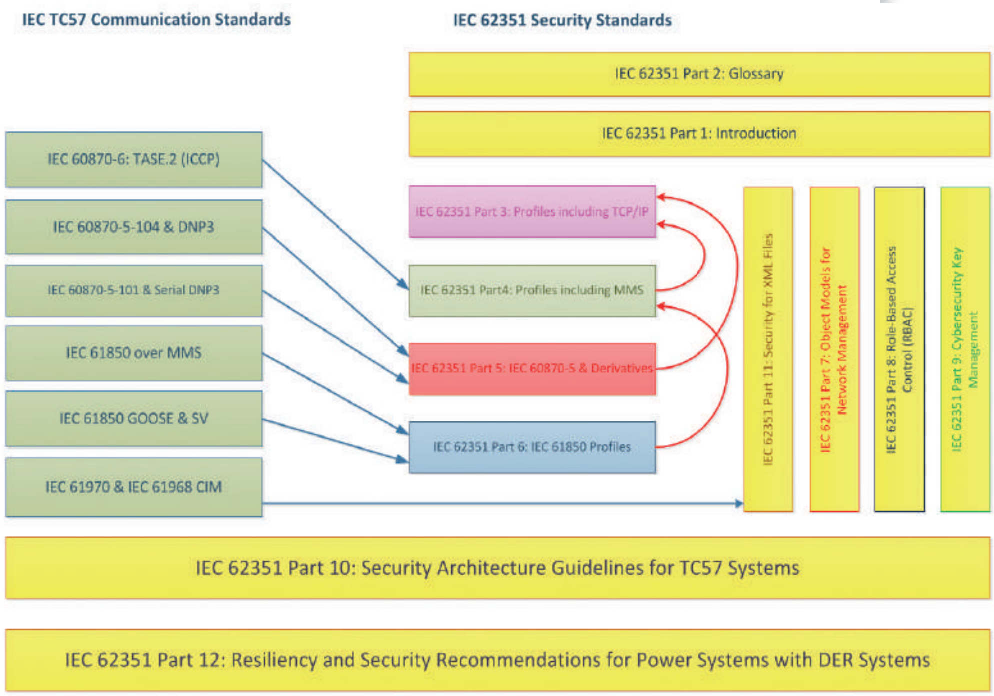
Currently, a number of important standardisation works on security are in progress at the EU level. The efforts to cover the gaps of standardisation on security in smart grids should be strongly supported and the coordination among the European and national initiatives should be enforced.
The role of SGIS - to make gap analysis and provide guidance and recommendations - is deemed essential.
The use of the SGIS Framework (formerly known as “SGIS Toolbox”) is highly recommended to perform risk assessments. It can also be used to guide through the selection and implementation of cyber security measures for the different use cases.
In general, the legal framework supporting security standardisation is feeble across Europe, with negative peaks in some countries. There is no sufficient fostering by utilities, and the sensitivity of end users is not developed enough. It is essentially a cultural issue. Policies at the EU and country level should be developed and implemented to overcome these barriers. Furthermore, considering the coverage of the smart grid evolution, the security/privacy/data protection law framework should be harmonised at the EU level.
Consumers and customers' data protection is the prerequisite for their participation in the business and the realisation of forecast benefits. Therefore, a wider sensitivity on data protection and privacy issues should be strongly fostered at the EU level.

Communications Networks for Smart Grid

Depending on the smart grid target applications, different types of communication networks and also collections of communication networks using different transmission technologies may be selected in order to transmit and deliver smart grid data. The following network types could be defined for the smart grids:

- Subscriber access network
- Neighbourhood network
- Field area network
- Low-end intra-substation network
- Intra-substation network
- Inter substation network
- Intra-control centre / Intra-data centre network
- Enterprise network
- Balancing network
- Interchange network
- Trans-regional / Trans-national network
- Wide and metropolitan area network
- Industrial fieldbus area network

(CEN-CENELEC-ETSI Smart Grid Coordination Group
First Set of Standards [5]).



Interconnection between communication and security standards

Expected Impact

The security issues associated with such an approach are difficult and expensive to implement, due to the complexity of the problem and the huge number of players and technologies involved. In fact, each node (player/technology) may introduce vulnerabilities in the system.
This approach requires that the security use cases be thoroughly defined, especially for the distribution grid. This is a very demanding job, requiring investigations, which may be carried out through specific R&D works. Functional use cases defined according to the security requirements are still missing, although they are being developed within some EU funded projects (e.g., SoES "Security of Energy Systems"). The elaboration of the use cases has been carried out by the SGCG-FSS maps connections, protocols and standards on the SGAM, but it does not go into details about the specification of security risks and requirements. EU funded projects may be the ideal context to develop an effective security framework to determine the best approach, the production of tools and guidelines, and the identification of best practices.
Utilities are concerned with the costs (not only for security but of smart grid implementation in general), and different attitudes against the issue may arise country by country, depending on their business dimensions and regulations. To this effect, the results of the EU FP7 project ESCORTS (European Network for the Security of Control and Real Time Systems, www.escortsproject.eu), which assessed the vulnerabilities of computer networks and SCADA architectures in the energy domain, should be considered.

Main Impacted Stakeholders

Network operators (energy and communication) are responsible for the security (physical and information) of the operated infrastructures and have to univocally define the requirements for their protection. They are also concerned with the associated costs.
End users are mainly impacted by privacy and data protection issues.

Increase Participation in the Standardisation Process

addressed to: standardisation bodies

Main Recommendation

Implement mechanisms and tools ensuring transparency of the standardisation process and the largest possible participation of all stakeholders' representatives, especially SMEs and end users. Enhance the role and foster the participation of sector associations.

Corollary Recommendations

• Simplify the access to standards and related metadata by providing publicly available information through a user-friendly online platform.

• Enhance visibility of working documents and the participation of stakeholders in the standardisation process by enabling public consultations and including standardisation activities in publicly funded projects.

• Cooperation frameworks among standardisation bodies, like SGCG, SMCG, eMCG, should be maintained and supported beyond the end of the respective mandates.

• Cooperation with industry initiatives performing pre-standardisation activities and developing own specifications on certain smart grid aspects should be fostered.

• Promote the Smart Grid Architecture Model (SGAM) as the central classification scheme for smart grid standards.

Dissemination

With the advent of the smart grid the necessity arises for many stakeholders of the electricity system to keep track of technological developments and standardisation activities in domains they were not traditionally concerned with and where they are not represented in a committee. This leads to new challenges for the standardisation bodies as well, who need to ensure an adequate dissemination of their activities. European Standardisation Organisations (ESOs: CEN, CENELEC and ETSI), as well as the International standardisation organisations (for instance, IEC and ISO), provide a lot of information on their websites about ongoing standardisation work, listing publications and projects for all technical committees and subcommittees. Although this is a valuable work, it remains difficult to really follow up on the developments from outside the committee since usually little information on the content of a new/revised standard is communicated before the public enquiry stage, and a structured search for standards according to classified content is not always possible.
A central database of existing standards and current projects, besides access via the web page of individual committees, would help to improve the visibility of standardisation projects. An elegant solution could be the inclusion of a current projects list in an online library, which also enables public access to drafts in the enquiry stage. Besides basic information like the responsible committee, planned publication date, title and abstract if available, etc., for current projects the database should also provide some information on the targets and the motivation of the work, and expected major changes in case of a revision.

Cooperation frameworks

Cooperation among standardisation bodies is essential for the harmonic development of the standardisation framework targeted at a multidisciplinary system like the smart grid one. Frameworks like SGCG, SMCG, eMCG should be maintained and supported beyond the end date of the respective mandates. The concept of a system committee should be fostered for the supervision of different technical committees' work. Generally, experts participating in the committees of a standardisation body have an excellent overview of the work within their own technical areas. However, they are sometimes not aware of the developments of other technical areas. Therefore, the knowledge should be made publicly available from all sides.

Contributions from publicly funded projects

Innovation projects constitute the ideal environment for the development, validation and assessment of new standards. Benefitting from the involvement of the whole value chain, innovation projects ensure development beyond the state of the art and share and promote the project outcomes among the stakeholders.
The publicly funded environment would guarantee standards applicability related to different technologies, thus contributing to a standardisation framework is directly in line with the technological developments.
Publicly funded projects may complement the necessary resources allocated for the implementation and validation of the reference use cases.
The inclusion of standardisation in innovation projects would represent an effective way to ensure the involvement of SMEs in the process and to increase their competitiveness on the market.

Good Practice 4: CENELEC Standards Evolution and Forecast

Important efforts have been made into tools mapping the development of standards (for example CENELEC Standards Evolution and Forecast available as a web tool on CENELEC website [6]). We strongly recommend developing such tools and marketing them to people not involved in a mirror committee and make them available to national organisations.

Good Practice 5: IEC Smart Grid Standards Map

The mapping tool of the IEC provides a user-friendly graphical overview on standards related to the smart grid, including also non-IEC standards [5].
Furthermore, it allows the searching of standards applicable to particular components of the grid (graphically and text-based).
The STARGRID consortium has likewise created a database of smart grid standards. It aims to allow for a fine-grained selection of standards, based on additional categories like publication date, issuing organisation, SGAM cells, etc. The latest draft is available at www.stargrid.eu.

Good practice 6: EU projects

Among the EC funded projects, the development of the Voltage Control Use Case within the activities of FP7 project SmartC2Net www.smartc2net.eu is a good example.
Other examples to be mentioned are Green e-Motion (www.greenemotion-project.eu) and Grid4EU (www.grid4eu.eu).

Main Impacted Stakeholders

Standardisation bodies are, of course, the major impacted actors of the recommendation. However, policy makers (EC and national governments) and national authorities have the responsibility to foster the harmonised and transparent standardisation process.

Expected Impact

Concentrating all available information in a single access tool and marketing of that tool should lead to better visibility and the information on the standardisation process should reach most of the impacted stakeholders. Although it could slow down the standardisation process, bringing together the ideas and experience in products, materials, processes or services of companies, academic experts, researchers, SMEs, consumers and regulators will lead to higher quality standards, should ensure consensus in standardisation activities and a high acceptability of those standards. Introducing standards development into innovation projects will ensure development beyond the state of the art and sharing and promoting project outcomes among stakeholders. Also it would represent an effective way to involve SMEs in the process and to increase their competitiveness on the market.

Photo: ASRO

Photo: ASRO

STARGRID workshop "Smart Grid: Global Standards for Global Market" at the Congress of Energy and Electric Equipment (CEEER 2013) in Bucharest (RO), September 2013

Implementation

The implementation of guidelines for stakeholders to be involved in standardisation must be implemented by the standardisation bodies. Funding agencies should promote standardisation contributions in innovation projects.

addressed to:
policy makers,
regulation authorities,
standardisation bodies

Harmonise the Regulation and Standardisation Framework for DER Interconnection Rules

ACER, under solicitation of the EC, entrusted ENTSO-E to issue regulations at the EU level ruling the connection of generators to the grid. In March 2013 this led to the delivery of the ENTSO-E RfG Network Code, approved by the ACER and currently *[Editor's note: January 2015]* in the comitology phase prior to becoming part of the EU laws body as an EU regulation. Starting from the Code's entry into force prevailing over any local regulations, a transition period of three years will allow national implementation processes to adequate their national codes accordingly. With the aim of giving guidance for national implementation of the RfG NC, ENTSO-E has also issued a dedicated implementation guideline in October 2013.
In the meantime at the EU level, standardisation organisations produced technical standards (e.g., EN 50438:2013 "Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks") and technical specifications (CLC/FprTS 50549 "Requirements for generating plants to be connected in parallel with distribution networks - Part 1: Connection to a LV distribution network and above 16A; Part 2: Connection to a MV distribution network", both currently *[Editor's note: January 2015]* at the approval stage) receiving the provisions of the code, with the objective of constituting reference for national implementations with further specifications of values and ranges of non-exhaustive requirements contained in the code itself.
These running initiatives clearly reflect the hurry to pose a quick remedy to the dramatic penetration of the energy resources and to the connected potential stability risks for the entire energy system.

Main Recommendation

Foster the coherent harmonisation of the regulations/standards framework ensuring effective, transparent and economically fair integration of DER in smart grids.

Corollary Recommendations

• Use European standards to provide guidance for a progressive alignment of the national legal frameworks avoiding product variance and facilitating further deployment of DER.

• The new standardisation approach is suitable to the scope. The opportunity of elaborating EN 50438 and coming TS 50549 1-2 so as to be part of a set of harmonised standards could be explored.

• Elaborate a regulation and standardisation approach to foster the integration of prosumers equipped with small and low cost equipment compatible with the system operation needs.

• Upgrade the standardisation process so as to foster a more active and conscious participation of stakeholders (see **Recommendation 5. Increase participation in the standardisation process**).

• Complete pro-actively the standards framework including new needs coming from the extended integration of DERs at LV grid level, e.g., concerned with the monitoring.

• Foster a mutual acknowledgment system, based on EU standards, for conformance testing related to smart grid and DER integration to promote competitiveness of industry and enhance the quality of products.

Expected Impact

Firstly, harmonisation and coordination of regulations/ standardisation initiatives prevents security problems in the system. Security and stability are paramount for the EU interconnected electric system and sharing of essential requirements is the basic reason of issuing common (and national) network codes and corresponding standards. Moreover, there is a certain concern from stakeholders, mainly generator producers, about a number of issues, which could arise from a non-sufficiently harmonised regulations/standards framework at the EU level concerning the integration of DER. These issues deal mainly with:

• New technical solutions, necessary to fulfil requirements varying from country to country

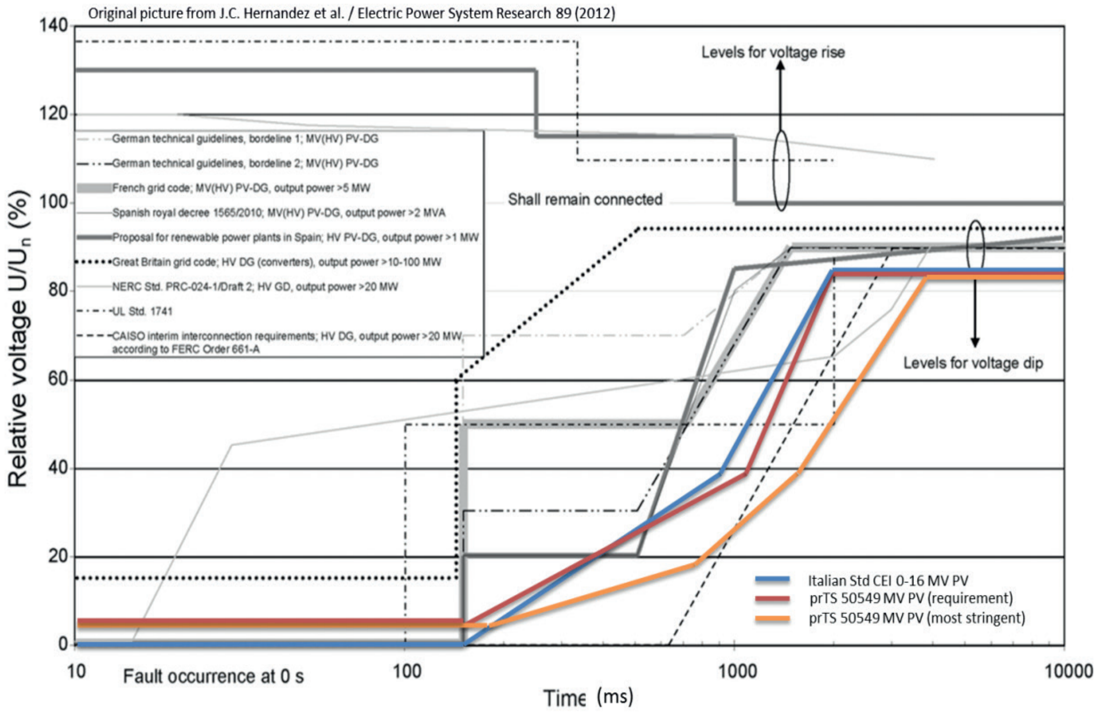
• Higher costs associated with the implementation of technical solutions

•Competitiveness conditions to access the energy market

The tendency to implement national regulation before consolidating the EU interconnection rules created country-by-country discrepancies. Of course, these discrepancies are justified by the need to deal with the local grid situations, but it is a fact that they may impact the industry competitiveness by constituting barriers to the free circulation of products in the EU. The following figure shows, as an example, deep differences in the EU in the LVFRT provisions for PV plants connected to the MV grid. New versions, variants, explanation guidelines following one another may generate confusion if not suitably coordinated, even though they are justified by the need of tracking changes in the reference document.
General requirements, in any case, should be fixed by standards, hopefully at the EU level, with at least a set of minimum mandatory specifications. Details on the implementation could be left to specific agreements with the grid operator according to their needs, within the limits set by the applicable standards or grid codes. In some contexts these agreements could be managed by intermediary stakeholders, e.g., aggregators.
Concerns could come to manufacturers and DER operators in case retrofitting is necessary for the integration of existing equipment in the grid according to the new rules. In general, such requirements should not be imposed without a prior cost-benefit analysis. In case prescribed capabilities are not technically implementable in a short-time period, the Network Code may give rise to delays in the erection of DERs.
The STARGRID survey of stakeholders and the analysis of specific standards related to integration issues evidenced other aspects, more tied to the consistency of the documents with real application conditions, which also need to be considered in the harmonisation process. Just to mention a case, compliance tests have high relevance in the RfG code. Corresponding standards should provide clear and detailed functional test specifications in order not to generate incongruent provisions for conformance tests with respect to the laboratory capacity. Designers and laboratory operators are the players mostly concerned in this aspect.

Main Impacted Stakeholders

Network (Transmission and Distribution) Operators are responsible for ensuring the security and the quality of the energy supply.
DER operators need clear integration rules supporting their business in a transparent way.
DER manufacturers and system integrators are concerned with the potentially higher costs and procurement delays caused by disharmonic rules and the differing approaches used in different countries.
Designers and manufacturers urge well-defined and coherent technical specifications.
Testing/certification labs request coherent requirements for conformance tests.



FRT capability proposed by new grid codes and standards to be supported by PV-DG without disconnection from the grid

Implementation

Harmonisation of the standards framework in the case of smart grid requires agreement on the options, considering the complexity of the system itself and of the stakeholders involved, often with conflicting interests. The concept of system committees, which is growing, e.g., in IEC [8], aimed to elaborate upper level models (i.e., the definition of system architectures), is deemed a good basis of an effective coordination of standardisation works in complex systems like smart grids.

The use of European standards will be crucial in providing guidance for a progressive alignment of the national legal frameworks avoiding product variance and facilitating further deployment of DER by better usage/understanding of DER capabilities.

Some stakeholders suggest that the evolution of TS 50549 1-2 Technical Specifications towards full EU standards should be fostered and sped up as it will trigger harmonisation and will facilitate further distributed generation deployment. This could be of great benefit especially for designers and constructors. A possible path, coherent with the standardisation new approach, is to generate a set of DER interconnection standards, including EN 50438 and future EN 50549 1-2, as harmonised standards. These latter standards could also include, in normative appendixes, national settings and requirements and detailed specifications for conformance tests.

A mutual acknowledgement system for conformance testing should be implemented for accreditation of laboratories dealing with smart grid and DER integration. This system should be based on a set of EU standards and procedures.

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Maintaining Grid Stability, Increasing Renewable Energy Supplies in DEA-Stabil

Info

DEA-Stabil: Examination and improvement of methods for maintaining grid stability while increasing the supply of decentralised renewable energy sources
Duration: April 2013 – March 2016
Funding: German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
Partners: Fraunhofer IWES, Enercon GmbH, Tennet TSO Gmbh, DERlab

The transformation of our electricity grid in the context of increasing renewable energy supplies requires an in-depth look on how we plan and regulate the grid to maintain its long-term stability. Launched in 2013 by Fraunhofer IWES, Enercon GmbH, Tennet TSO Gmbh, and DERlab e.V. and funded by the German Federal Ministry for the Environment, Nature Conversation, Building and Nuclear Safety, the DEA-Stabil project aims to examine how the influx of renewable energy sources will impact the transmission grids based on a number of instability scenarios identified and developed for this project. The project partners investigate the range of suitable tools that can be used to maintain stability in the German grid. Following this, they will see how these methods can be expanded and improved with the help of hardware-in-the-loop facilities created for this project.

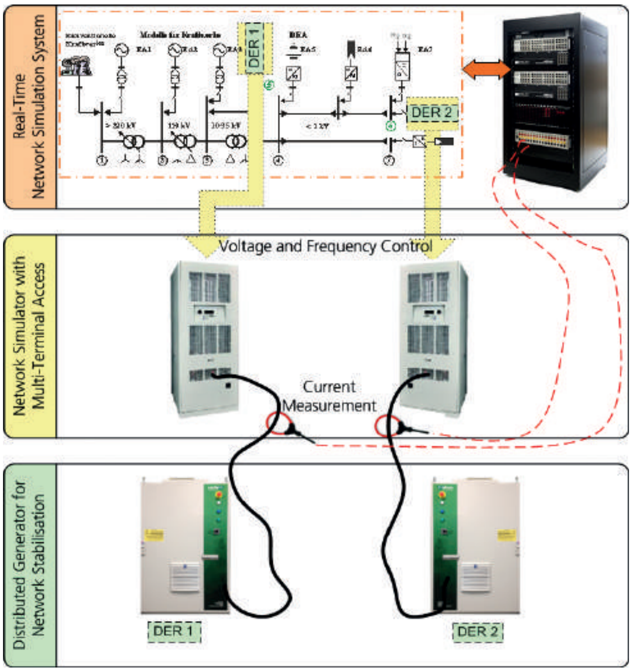
While the initial grid stability analysis is performed for the German electricity grid, the European electricity grids are highly interconnected and will become even more so in the future. Therefore, the initial recommendations will be adjusted to individual European countries and their local regulation systems and requirements. For this purpose, DERlab is surveying national, European and international standards, standardisation bodies, and regulations of national DSOs as well as technical guides relevant to DER grid connectivity. In addition to regular reports and dissemination efforts, DERlab records these findings in an open database www.dergridrequirements.net.

Power generation technologies covered by the database include PV, combustion-based power generators, energy storage systems, wind turbines, hydraulic turbines, and fuel cells. Further relevant topics include:

- conformity evaluation procedures
- smart grid communication systems and cyber security
- design guides for DER systems and electronic-based inverters used in such systems
- guides regarding electromagnetic emissions
- installation maintenance, monitoring, and safety guides
- requirements for energy output quality
- guides on testing DER systems and related equipment

The database has meanwhile been complemented with the information for Austria, Germany, Ireland, Latvia, the German-speaking parts of Switzerland, and the United Kingdom.

With the goal to bring industry expertise into the project, the project consortium founded the Industry Working and Advisory Group to review the project findings and advise upon the project methods and objectives. It held its first regular meeting on 29 January, 2014, in Berlin. Its members - in addition to Fraunhofer IWES, Enercon, Tennet, and DERlab including MitNetz Strom mbH, Bayernwerk AG, SMA, and Forum Netztechnik/Netzbetrieb - advise the project partners on industry concerns relating to grid stability and provide input for developing plausible test scenarios.



Hardware-in-the-loop test stand to be developed for DEA Stabil

Source: Fraunhofer IWES

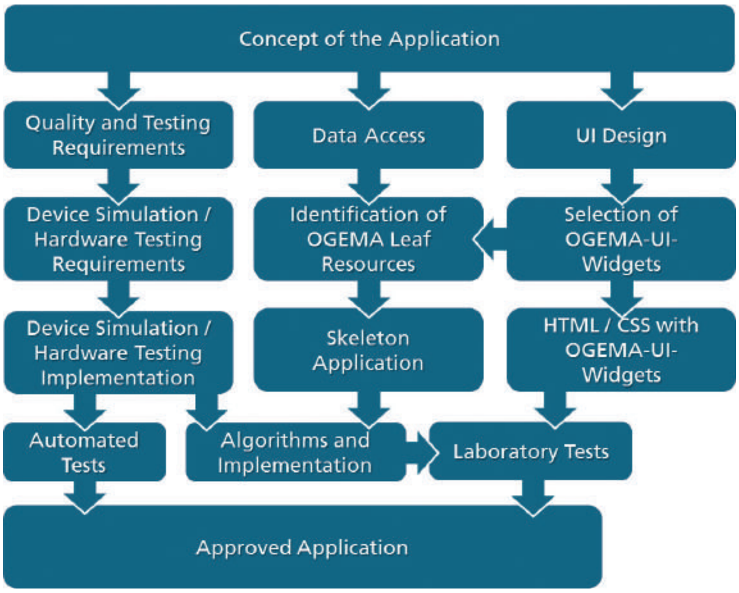
Automation and Energy Management Solutions for Neighbourhoods in EEPOS

Info

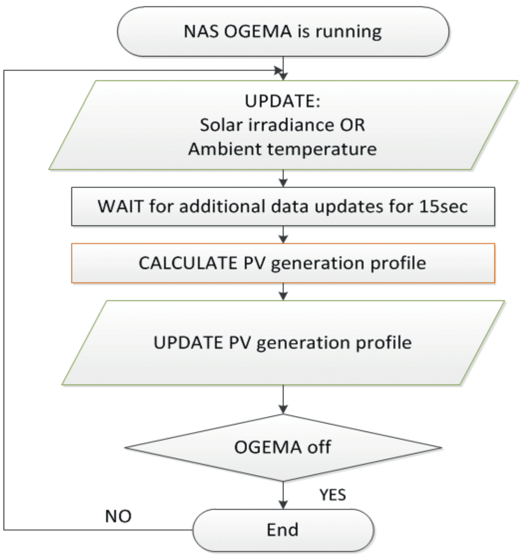
EEPOS: Energy management and decision support systems for Energy POSitive neighbourhoods
Duration: October 2012 – September 2015
Funding: The Seventh Framework Programme of the EC
Partners: The EEPOS consortium includes eight academic, industrial and public organisations from four European countries located in different EU climate zones

You can find further information about EEPOS, project outcomes and events on **www.eepos-project.eu**

You can find further information about OGEMA on **www.ogema.org**



Application development methodology



PV generation forecast application

Due to the increasing deployment of renewable energy sources in local grids, the local electricity supply often far outstrips local consumption. This leads to transmission losses even if there is a demand elsewhere, and the excess may be fed into higher level grids. Other regions frequently encounter the same disparity between production and consumption. Meanwhile, renewable energy sources are often unable to meet the need in times of peak demand, even in local grids with high penetration. It is the goal of the EEPOS project to address this mismatch by shifting consumption away from their former peaks towards times of high production and thus contribute to grid stability and the efficient use of renewable energy.

DERlab has completed the first analysis of the approach taken in EEPOS, which is based on a neighbourhood-level analysis of load prediction, prediction of PV production, and time-variable electricity prices. This approach sends "adaption requests" to individual households, suggesting either an increase or a decrease in electricity consumption based on the needs of the current and predicted future electricity balance as well as the stability of the local grid. These adaption requests are provided 24 hours in advance in 15 minute increments and are computed for each household individually. This makes the system more flexible and prevents electricity consumers from switching on or off simultaneously and endangering grid stability in the process. These adaption requests can be used to either automatically control electrical consumers and thus shift their load with minimal human input or allow the inhabitants of the individual households to adjust their consumption patterns manually.

Above: Merenkulkijanranta neighbourhood area in Helsinki
Below: Kaspar Pae, Dan Hildebrandt and Mikko Tuomi working with the JACE interface on the EEPOS project demonstration site in Helsinki

Case #	Price	Residual load	Load shifting signal	Action
1	High	Positive peak	-2	Shift load FROM these times (strongly suggested)
2	High	Positive & Not peak	-1	Shift load FROM these times
3	High	Negative	+2	Shift load TO these times: (strongly suggested)
4	Low	Any & Not off-peak	+1	Shift load TO these times
5	Low	Off-peak	+2	Shift load TO these times: (strongly suggested)

Optimal load shifting planning application

This energy management approach will be further tested in EEPOS field demonstration sites in Helsinki (Finland) and in Langenfeld (Germany) to examine how different levels of variable loads within a neighbourhood can contribute to grid stability.

For the field demonstrations and a laboratory prototype, DERlab and the Fraunhofer IWES are jointly developing a neighbourhood automation and management system based on the OGEMA Open Source Energy Management Framework. This system will collect information from both the neighbourhood and the household levels and use this data to generate adaption requests for the individual households participating in the field demonstration sites. The same system will be also used in a laboratory prototype where the households and their consumption behaviors are simulated by networked computers. This interconnected system intends to provide insight into scenarios for both manual and automated load shifting which cannot be part of the field demonstration sites for technical reasons.

Sea view from the roof of an EEPOS project demonstration building in the neighbourhood area Merenkulkijanranta in Helsinki with the building Ruffi on the right.

Strengthening PV Research in SOPHIA RI

Info

SOPHIA RI: Photovoltaic European Research Infrastructure brings together research organisations across Europe to optimise the use of research infrastructures and improve their performance
Duration: February 2011 – January 2015
Funding: The Seventh Framework Programme of the EC
Partners: 18 European research institutes and DERlab, the European Photovoltaic Industry Association (EPIA) and the European Renewable Energy Centres Agency (EUREC)

You can find further information about SOPHIA, project outcomes and events on **www.sophia-ri.eu**

The SOPHIA Research Infrastructure project aimed to strengthen and optimise PV research capabilities mainly by coordinating efforts on precompetitive topics. The project also addressed the issues of fragmentation and costly research duplication on the European scale.

Within the SOPHIA Research Infrastructure project, DERlab has contributed to the Joint-Research-Activity "Uncertainties Evaluation for Long-Term Photovoltaic Module Outdoor Tests" by:

- **Identifying the measurement periods, plausibility checks, uncertainties evaluation and recording time intervals**

- **Organising the webinar "Uncertainty estimations of PV outdoor measurements" in 2013 with four other project partners and 38 participants**

- **Developing technical guidelines for energy yield measurement of PV modules in outdoor conditions, the related testing setup and the requirements for the measurement equipment accuracy, which you can find in the DERlab Shop www.shop.der-lab.net**

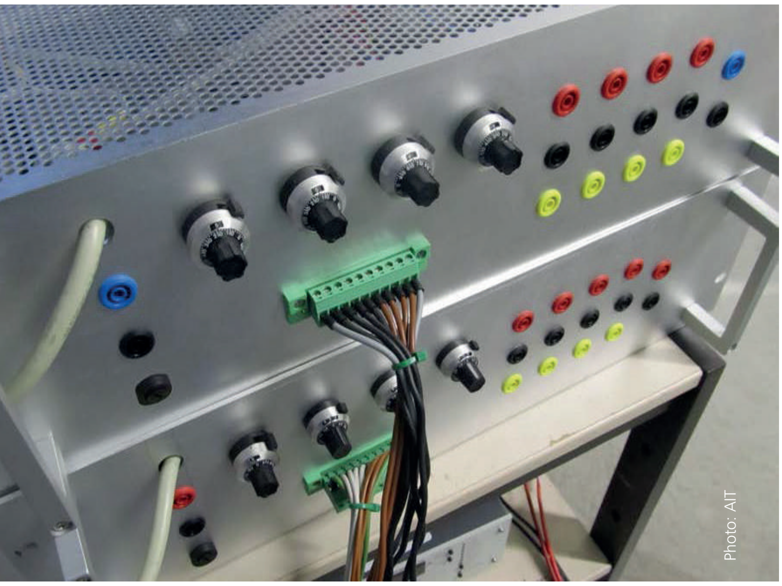


Figure 1: DC high voltage sources for PID tests

With respect to the variation of measurement infrastructures, uncertainties in energy yields prediction become one of the most critical issues for investors, operators and manufacturers. SOPHIA addressed the reduction of these uncertainties on the module level and carried out the following activities:

- setting up a standardised data format and database structure for modelling activities and for the quality management of the data acquisition and the standardised data filtering process

- developing/adapting the power output prediction models and module backside operating temperature models based on the measured data from experimental fields and predicting the energy yields based on the measured data from practical fields from different locations around Europe

- setting up the evaluation framework for a uniform assessment of the different models, especially the yearly energy yields for project planning and investment aspects

- comparing the prediction models based on different modelling approaches

- evaluating different parameters affecting the characteristics of PV modules, e.g., influence of the ambient temperature and the module backside temperature based on the practical and experimental measurement respectively

The final project event Symposium on European PV Research

Data acquisition including IV-curve tracer of PV modules in the workshop "Best Practices for Power Measurement of Photovoltaic Devices" in JRC-Ispra, July 2014

Infrastructures highlighted the main outcomes of SOPHIA and served as a forum for discussion on the type of PV research infrastructures and e-infrastructures required in Europe in the next decade. The event took place on 22 January, 2015, in Chambery, France, where 20 European partners discussed major PV topics.

Another major activity of the project was offering partner organisations and researchers from outside the consortium the possibility to share their experiences, receive training and enhance research activities in the PV research infrastructures by the means of the so called TransNational Access (TNA). Seven DERlab members have also been involved in the TNA activities: Research Center for Sustainable Energy (FOSS) of the University of Cyprus, AIT, CEA-INES, DTU, RSE, TECNALIA, and Enel.

Within the TNA in summer 2014, FOSS was hosted by the SOPHIA consortium member Austrian Institute of Technology, Energy Department (AIT Energy). The research focused on PID in ageing tests of PV modules in a climate chamber. Figure 1 shows a setup allowing the connection of up to eight PV modules to individual stabilised DC sources with the voltage up to ±2000 V and measuring the leakage currents as well as dark I-V curves of these modules periodically.

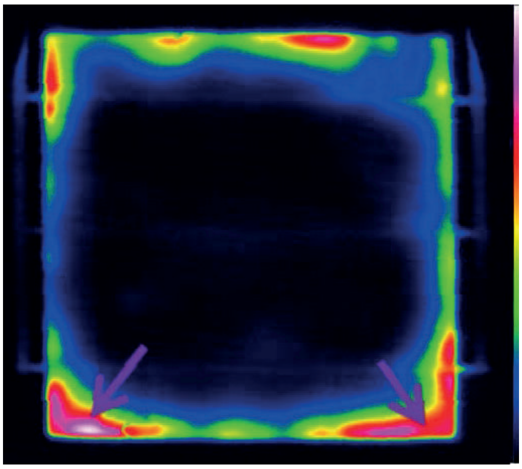
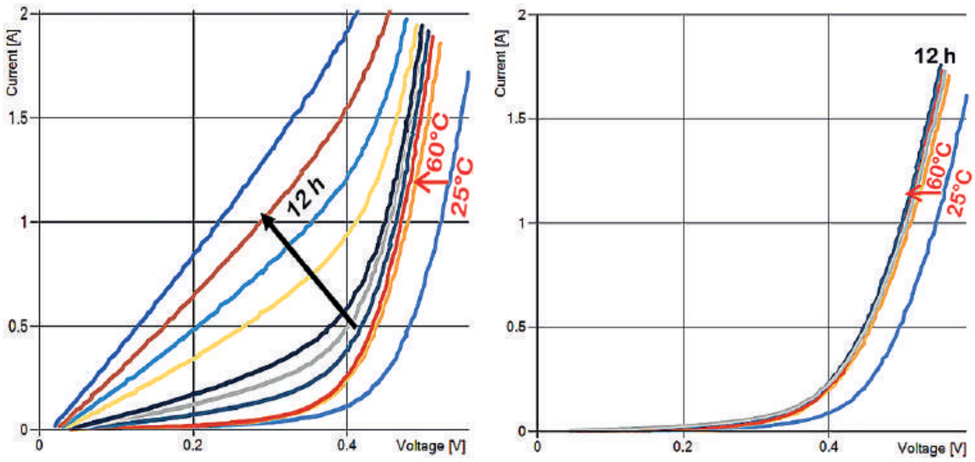


Figure 2: Dark lock-in thermography of a single-cell module

Figure 3: Dark I-V Curve of two different single cell modules measured in a climate chamber at the AIT

Source: AIT



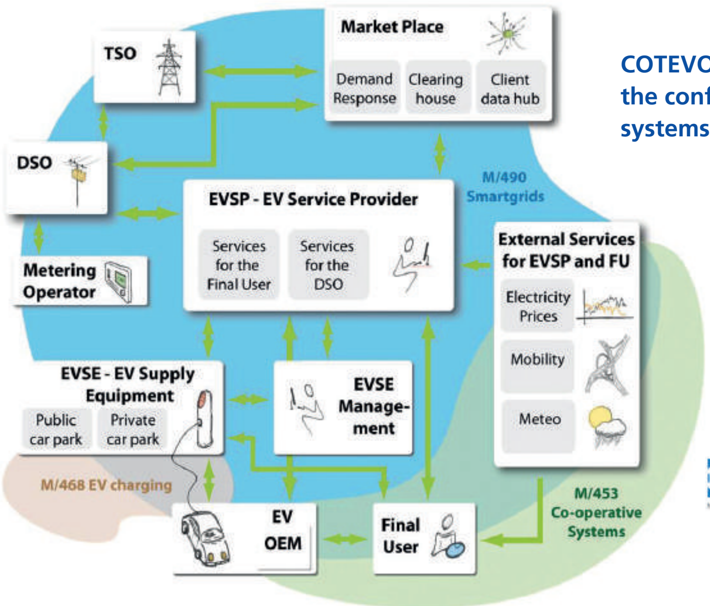
DERlab Members Working on EV Integration Test Cases in COTEVOS

Info

COTEVOS: COncepts, Capacities and Methods for Testing EV systems and their interOperability within the Smart grid
Duration: September 2013 – February 2016
Funding: The Seventh Framework Programme of the EC
Partners: 10 partners and DERlab
External parties: National Renewable Energy Laboratory (NREL), University of Strathclyde, Institute of Communication and Computer Systems (NTUA-ICCS)

You can find further information about COTEVOS, project outcomes, events and more on **www.cotevos.eu.**

EVs emerge as a great challenge for the grid infrastructure. In order to promote the adoption of electric vehicles (EVs) in Europe and to reduce the multiple regulatory, commercial and political barriers, EVs, charging points (CPs) and all kinds of systems and stakeholders need to be assessed from different perspectives, such as those of the electric energy, communications and information management.



COTEVOS aims to develop optimal structures and capacities to test the conformance, interoperability and performance of the different systems in the infrastructure for smart charging of EVs.

Left: EV charging infrastructure and the COTEVOS concept
Below: an overview of the COTEVOS partners and external parties (NREL, NTUA-ICCS, University of Strathclyde)

From a global point of view, COTEVOS and its eleven partners aim to bring together current research effort in electro-mobility and, therefore, maximise its efficiency through the collaboration with the third parties in the EU countries and beyond: University of Strathclyde, NTUA-ICCS, and NREL. Due to this cooperation, COTEVOS is an unprecedented example of an EU electro-mobility project working beyond the scope of its European partners.

Electric cars at the premises of DTU, Roskilde (DK)

As its first milestone, COTEVOS has investigated market solutions available in the electro-mobility field today. The project partners used this data to define their future strategies for interoperability assessment. The following table summarises partners' opinions and strategy. The latter is represented by the protocols that will be implemented in the laboratory environment (last column). The vision on the standardisation relevance of the interfaces between actors, as well as on the expected market interest and the implementation costs for each of them, is summed up in columns 3 to 6 in the table. Possible answers for concept assessment were limited to High (H), Medium (M) or Low (L).

Communication		Standardisation relevance	Market interest		Cost	COTEVOS partners' expected services
from	to		Short term	Medium / long term		
Secondary Actor system	ICT platform	L-M	L-M	M-H	L-M	OCHP: 1 partner
EVSE	ICT platform	M-H	L-M	H	L-M	
Secondary Actor	Secondary Actor	M-H	L-M	M-H	M	IEC 62746: 1 Open ADR, OSCP, PowerMatcher: 1
DSO	HEMS	H	L	M-H	L-M	
DSO	EV	M	L	L-M	M-H	Not specified: 1 IEC 61850, OpenADR, Proprietary: 1
DSO	EVSE	M-H	L	M-H	M-H	Not specified: 1 IEC 61850, OpenADR, Proprietary: 1 IEC 61850-90-8: 1
DSO / Retailer	Energy customer	M	M-H	H	L	
HEMS / smart meter	EVSE/smart socket	M	L	M	L-M	
Fleet manager	EV	M-H	L	M-H	M	
EVSEO	EVSE	H	M	M-H	M	OCPP: 4
EV user	Secondary Actor and ICT systems	L-M	L	M	L	
EV user	EVSE	H	H	H	L-M	RFID: 1
EVSE	EVSE	L	L	L	L	
EV	ITS platforms	M-H	L	M	M	
EV	EVSE	H	M-H	M-H	M-H	IEC 61851: 6 partners IEC/ISO 15118: 5
EV	Smart socket	M	L-M	M-H	L-M	
EV	EV user	L-M	L	M-H	L	
EV	EV (ITS)	M	L	M-H	M	
EV	EV (Inside the Vehicle)	L-M	L	L-M	L	

By being in close collaboration with European EV initiatives, equipment manufacturers, service providers, utilities and industrial networks, COTEVOS seeks a collective EU approach to the EV interoperability and smart charging.

On 2 October, 2014, COTEVOS held the workshop "Plans for Interoperability Assessment Infrastructures and Test Cases for EV Integration" for its partners and involved third parties. Collocated with the project's general assembly meeting at the premises of DTU in Roskilde, Denmark, the workshop reviewed the COTEVOS role, its interaction with standards, and the COTEVOS infrastructures for interoperability assessment among other topics.

The workshop benefited from the participation of not only project partners but also external parties and industry representatives. The participants tackled the topics of the EV integration system architecture based on the SGAM Model and the test cases implementation and round robin tests within COTEVOS. Among other topics raised at the workshop were interoperability needs, required infrastructures, and business opportunities for interoperability assessment.

By the end of 2015, COTEVOS will arrange an EV interoperability plug-test workshop in cooperation with external partners. This event will provide all stakeholders in the EV business the chance to test conformance, interoperability and performance of multiple systems and vendors.

COTEVOS workshop "Plans for Interoperability Assessment Infrastructures and Test Cases for EV Integration" at the premises of DTU in Roskilde (DK), October 2014

Access to Smart Grids Research Infrastructure in ELECTRA

Info

ELECTRA IRP: European Liaison on Electricity Committed Towards long-term Research Activity Integrated Research Programme
Duration: December 2013 – November 2017
Funding: The Seventh Framework Programme of the EC
Partners: 19 research institutes, DERlab and JRC -Joint Research Centre - European Commission

For further information please visit
www.electrairp.eu **www.eera-set.eu**

The ELECTRA Integrated Research Programme on Smart Grids brings together the partners of the EERA Joint Programme on Smart Grids (JP SG) to reinforce and accelerate Europe's medium- to long-term research cooperation in this area and to boost closer integration of the research programmes of the participating organisations and of the related national programmes. ELECTRA's joint research activity and collaborative support actions build on an established track record of collaboration and engagement.

Together, the JP SG and ELECTRA will establish significant coherence across national research efforts, critical to the stable operation of the EU power system of 2020+. The EU energy strategy sets ambitious goals for the energy systems of the future that foresees a substantial increase in the share of renewable electricity production.

The ELECTRA IRP develops radically new control schemes for the real time operation of the 2030 power system. This will enable grid operators to ensure dynamic balance and stability in a future power system with a high share of decentralised generation.

The ultimate goal of ELECTRA is to test the developed new control concepts at the experimental level and in such a way that industrial stakeholders can implement these innovative solutions in field testing activities in a subsequent phase.

In particular, simulation environments and lab experiments will be realised to investigate and evaluate the exploitation of flexibility in voltage and frequency control schemes and to visualise, simplify and overcome the increasing complexity in the future power system.

DERlab's main task is to lead the ELECTRA project's international collaboration with ISGAN's Smart Grid International Research Facility Network (SIRFN). DERlab carries the role of the Operating Agent of ISGAN Annex V (SIRFN) and, in the frame of the ELECTRA project, supports the context of international knowledge sharing and discussions on testing and validation of smart grid controls (focusing on voltage and frequency control) in research facilities around the world.

In November 2014, DERlab organised a joint DERlab/SIRFN workshop as a side event at the IRED 2014 where SIRFN labs discussed current and future cross-lab research projects involving advanced DER interoperability testing, smart grid modelling, and power system component testing.

DERlab further developed and continuously maintains a European smart grid infrastructure database, based on the DERlab Database of DER and Smart Grid Research

Session C (Forecasting for Smart Grids) of the three one-day workshops held at Strathclyde University in Glasgow (UK) on 7 May, 2014

ELECTRA IRP Advisory Board Meeting in Brussels (BE) on 17 December, 2014

Infrastructure (www.der-lab.net/derlabsearch). The database hosts information on more than 45 research institutes with over 215 research infrastructures, offering an overview of their facilities, research focus, test labs capabilities, testing accreditations, testing compliance, available equipment. The database is constantly updated and features available simulation/ optimisation tools, related libraries, and testing protocols. This database also provides information with respect to provisional users' access to specific research infrastructure or testing facilities available within the ELECTRA Consortium, as well as publicly available information on the infrastructure use cases and technical results.

A side event named "ELECTRA IRP/EERA Smart Grids Workshop and the Aim towards International Cooperation" was organised at the IRED 2014 on 17 November, 2014. The workshop gave its participants the opportunity to learn about the latest results of the EERA JP SG and ELECTRA IRP research programmes, discuss concepts crucial to the emergence of radical integrative voltage and frequency control solutions, and attend the global launch of the ELECTRA Researcher Exchange Programme. You can find further information on the event on www.nedo.go.jp/english/ired2014.

ELECTRA Call for Researchers Exchange

The Exchange Programme Management Committee of the ELECTRA IRP is announcing several calls for applications for Researcher Exchanges among ELECTRA Partners, and between ELECTRA Partners and international organisations. The call is open to the whole research community and aims at training researchers, establishing a deeper culture of awareness and cooperation amongst European smart grids researchers as well as strengthening research understanding in smart grid controls between international partners.

Find more information in the Mobility section on www.electrairp.eu

Contribution to the Smart Grids Roadmap of the European Strategy Forum on Research Infrastructures (ESFRI)

Within the ELECTRA framework in autumn 2014, DERlab contributed to the ESFRI Roadmap consultation. The Roadmap identifies new Research Infrastructures (RI) of pan-European interest corresponding to the long-term needs of European research communities, covering all scientific areas, regardless of their possible location.

DERlab gave an overview of the current research infrastructure and related testing capabilities and services available internationally. DERlab also contributed to the identification of the main challenges in Strategic Research Agendas and innovation cases, which can be covered by the ongoing and future research and testing performed within the existing research infrastructure.

European Coordination of Smart Grids Research

Luciano Martini on EERA JP on Smart Grids

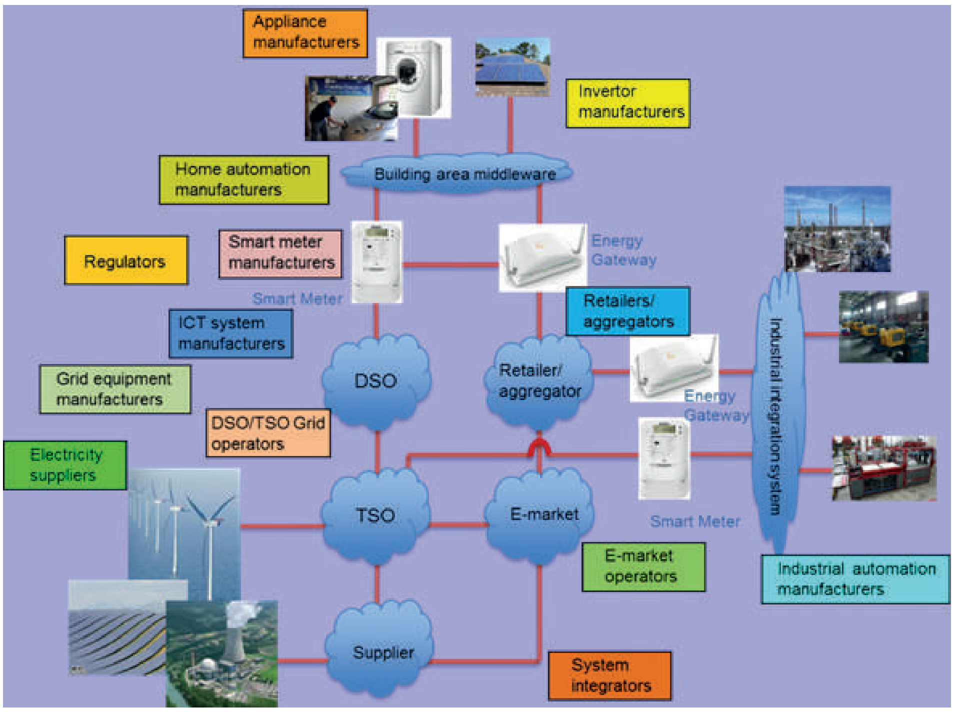
Luciano Martini
Coordinator of the European Energy Research Alliance (EERA) Joint Programme on Smart Grids

The main goal of the EERA Joint Programme (JP) on Smart Grids is to promote the European coordination of smart grid medium- to long-term research activities in order to avoid gaps and to minimise excessive overlapping. Hence, one of our main tasks is to align and coordinate the research efforts of the member states to elevate the results to the European level with the aim of steering the national smart grid research programmes.

It is believed that this can only be fully accomplished if the research organisations aligning their forces in the EERA JP SG - currently 20 participants and 16 associate participants representing 17 EU countries - closely interact and collaborate with the European Commission and the organisations representing the industrial grid stakeholders, such as the EEGI, ENTSO-E, EDSO4SG, and the ETP SmartGrids.

The EERA JP on Smart Grids R&D activities range from studies, simulations and analyses to the assessment and validation of the main findings at the laboratory level. These activities help EERA JP SG involved research institutes to contribute in specific complementary areas of R&D and to consolidate the results of national programmes in the direct support of the European strategic energy objectives.

Through the EERA JP SG, in a coordinated manner across Europe, we promote research on, for example, new control strategies and more advanced technologies, still in a pre-



Example of a smart grid system with various stakeholders and the interfaces through which they exchange information

EERA JP SG members prior to the technical visit to the Alpha-Ventus off-shore wind farm as a side event of the Steering Committee meeting organised by OFFIS in Oldenburg (DE), October 2014

competitive stage as possible solutions in the 2030 power system. Presented and openly discussed at related international workshops, the main outcomes of the EERA JP SG research are summarised in publicly available reports on www.smartgrids.eu.

"The strength of the EERA JP SG and the ELECTRA IRP resides in the skills and experience of the participating organisations and in their commitment to working in a coordinated manner. "

ELECTRA Integrated Research Programme (IRP) on Smart Grids - launched in December 2013 - provides strong support to this approach, which is certainly instrumental to the EERA JP SG goals and outcomes.

The strength of the EERA JP SG and the ELECTRA IRP resides in the skills and experience of the participating organisations and in their commitment to working in a coordinated manner. In fact, through its members the EERA JP SG and the ELECTRA IRP promote the interaction among multiple national and European initiatives, including the cooperation with EEGI and with the ETP SmartGrids that is of utmost importance for Europe as a whole.

Moreover, relevant actions in specific areas have been made possible, and some of them are mentioned in the following as well as the key actors involved.

In particular, major smart grids research infrastructures pertaining to each of the EERA JP SG involved participants are also devoted to the coordinated R&D activities. So according to its mission, DERlab is the partner leading the activities towards a more effective use of these existing research infrastructures with the special focus to identify best practices of laboratory testing for systems and components towards the optimisation of suitable test procedures. Furthermore, key members of the completed EU project DERri use their experience to promote researcher exchange.

Since international collaboration in research results exchange and the priority of R&D topics in smart grids is certainly of major importance to us, all members take certain actions beyond bilateral collaboration agreements.

Based on our past cooperation with extra-European partners, we see that Europe and European industries are in the position of frontrunners. With our initiatives we set out to keep at it and strengthen this European leading position.

Enhancing PV Distribution Grid Capacity

PV GRID Concluded with Solutions, and Implementation Recommendations

In September 2014, the PV GRID project held its final event in Brussels, Belgium, where it presented results on the technical and regulatory solutions for a smoother integration of high shares of photovoltaics (PV) into the grid.

The project's main goal of reducing legal, administrative and regulatory barriers to the large-scale integration of PV systems in electricity distribution infrastructures across Europe has been achieved by analysing barriers, solutions and by articulating regulatory and normative recommendations. Thus, the EU member states engaged in the knowledge transfer enabled by the European scope of the project.

PV GRID concentrated on two areas of activities: on the one hand, the continuous assessment of national frameworks for the development of PV installations, and, on the other hand, the relation between certain legislative, regulatory and normative frameworks and the identified technical solutions available to increase distribution grid hosting capacity. Within the first area of project activities, the assessment of national frameworks for PV development is made possible by the PV GRID database (www.pvgrid.eu/database).

Info

PV GRID: Overcoming regulatory and normative challenges linked to the integration of high shares of PV electricity in the distribution system across Europe
Duration: May 2012 – October 2014
Funding: Intelligent Energy Europe Programme of the EC
Partners: 20 project partners including National PV industry associations, the European Photovoltaic Industry Association (EPIA), DERlab, three Distribution System Operators (DSOs), eclareon, COMILLAS
Coordinator: German Solar Industry Association (BSW-Solar)

You can find further information about PV GRID, project outcomes, events and more on **www.pvgrid.eu.**

PV GRID
Make it smart!

Photo: EPIA

Final European PV GRID Forum in Brussels (BE), 29 September, 2014

The identification, prioritisation and analysis of available technical solutions enabling higher shares of PV in the distribution grids, were coordinated by DERlab with support of DSOs and other electricity sector experts in the four focus countries of the project: Czech Republic, Germany, Italy and Spain. DERlab led the central work package of PV GRID, coordinating technical discussions, reviewing and evaluating technical solutions both for the network and the consumer, and for the PV system. DERlab's main goal here was to identify intelligent approaches to the management of distribution grids.

The outcomes and the major papers of the project, such as the PV GRID Final Project Report summarising all project results and outcomes and the Advisory Paper presenting the barrier analysis and corresponding recommendations, can be found on the project website www.pvgrid.eu. The Advisory Paper also features eight national case studies further detailing the barrier analysis and recommendations for the four focus countries and other four promising PV markets: France, Greece, the Netherlands and the United Kingdom.

"PV Grid taught the participating organisations various lessons on the efficiency of PV grid integration. Especially the discussion among all key national stakeholders (regulators, TSOs, DSOs, PV sector and the smart grid/distributed generation sector at large) about the solutions and recommendations is of paramount importance in order to succeed in the implementation of the best approaches at a national level.

The solutions advocated by PV GRID can all help to integrate more PV in distribution grids, but there is no silver bullet amongst them. The choice of the solutions to be implemented heavily depends on the national policy and economic contexts.

At the European level, policy action should be taken in order to facilitate and harmonise such solutions. In particular, the grid codes development process shall take into account its repercussions on distributed generation and network infrastructures operation. Another important finding of the project is the need to clearly define terms and concepts involved in PV integration, as both extremely complex technical matters and language barriers often led to stakeholders misunderstanding each other in discussions, even when using the same words."

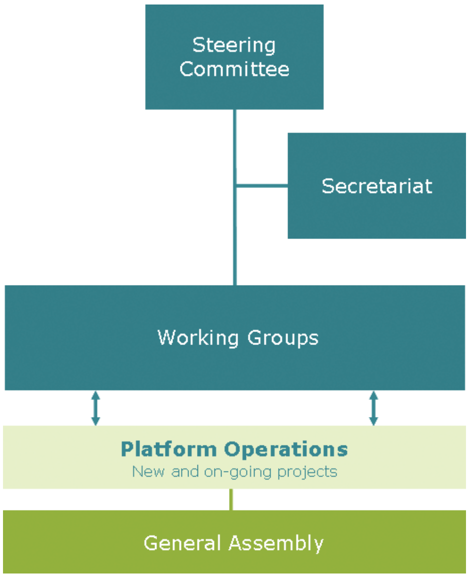
Jörg Mayer, Managing Director of the German Solar Energy Association (BSW-Solar)

Network Operation Issues Addressed by the European Technology Platform on Smart Grids and ELECTRA

Info

SmartGrids-ETPS-III: Secretariat of the European Technology Platform for Electricity Networks of the Future
Duration: October 2012 – October 2015
Funding: The Seventh Framework Programme of the EC
Partners: Zabala Innovation Consulting, Bacher Energie AG, KU Leuven and DERlab

For further information please visit
www.smartgrids.eu



The European Technology Platform for Electricity of the Future (ETP SmartGrids) brings together key stakeholders from the electricity networks sector, network operators, generation, technology suppliers, research community, regulators and related European and global organisations, platforms and initiatives. Part of the ETP secretariat since 2012, DERlab organises events and workshops thus supporting the working groups in reaching policy and investment decisions.

Since 2005 the platform has been supporting the research and development of smart grids technologies in Europe. Published in 2012, its key document Strategic Research Agenda 2035 determines the research priorities in the field and represents the stakeholders' views on the major areas to be investigated to advance the European Electricity Grid.

The work of the Technology Platform is driven by three Working Groups:

- Working Group 1 Network Operations and Assets
- Working Group 2 Energy Storage and Grid Integration
- Working Group 3 Demand Side, Metering and Retail

Joint Technical Workshop on Network Operation

On 17 December, 2014, DERlab organised a technical workshop on Network Operation for 2030+. Working Group 1 of the ETP SmartGrids together with the ELECTRA IRP invited interested stakeholders to the event in Brussels, where the three topics of discussions were:

- Inertia and grid stability with high penetration of DG and storage
- Operational flexibility and ancillary services
- Observability and system integration

The successful event attracted around 40 participants from all over Europe, who shared their experiences and opinions on Network Operation for 2030+ and beyond. Although mostly a technical workshop, the event also touched upon market views. The outcome of the workshop is available online on www.smartgrids.eu and on www.electrairp.eu

ETP SmartGrids at the Hannover Messe

In April 2014 DERlab supported the plan to represent the ETP at the Smart Grids Forum of the Hannover Messe. Jochen Kreusel, member of the Steering Committee of the ETP SmartGrids, held a successful presentation on the work of the platform, facilitating networking with representatives of national smart grids initiatives.

Cooperation with National Technology Platforms on Smart Grids

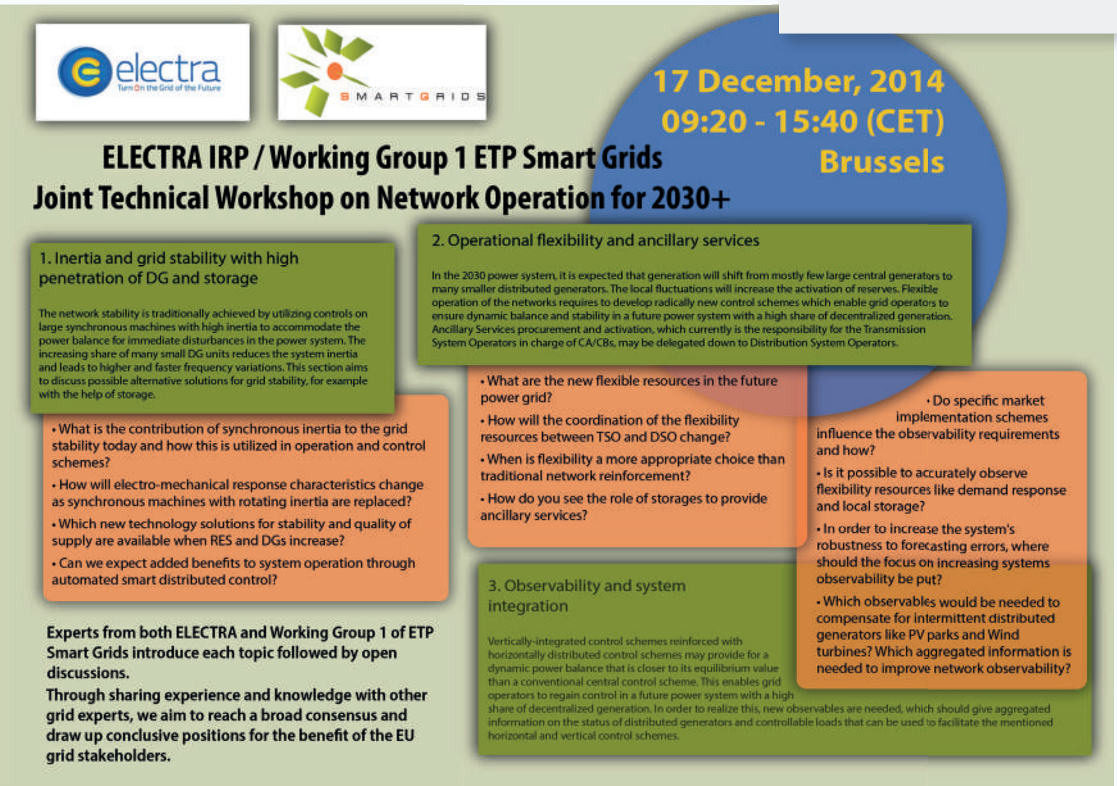
Networking with national initiatives on smart grids is one area of the future actions of the platform. Understanding national priorities will provide a key insight into how the ETP can support local advances most efficiently. For this purpose, in late 2014 the initiatives were invited to provide related information in form of a questionnaire. In order to establish a continuous dialogue and discuss the questionnaire outcomes, DERlab will support the organisation of a workshop in April 2015, attached to the ETP SmartGrids General Assembly in Brussels.

ETP SmartGrids General Assembly 29 April, 2015

Main topics:

- The ETP SmartGrids view on the future work programme 2016-2017 under Horizon 2020
- The ETP SmartGrids cooperation with national technology platforms on smart grids

The event aims to communicate the ETP SmartGrids activities – the ones completed since the last General Assembly as well as those foreseen for the future. Members of the ETP SmartGrids, representatives of national technology platforms on smart grids and stakeholders in smart grids in Europe are expected to be among the event participants.



Above: ELECTRA IRP / Working Group 1 ETP Smart Grids Joint Technical Workshop "Network Operation for 2030+" organised by DERlab

ETP SmartGrids: European Collaboration Specifics and Final Challenges

Interview with Nikos Hatziargyriou

Nikos Hatziargyriou

- January 2015-present - President of the ETP SmartGrids
- 1995-present - Professor at the Electrical and Computer Engineering Department of the National Technical University of Athens
- 2007-2012 - Executive Vice-Chairman and Deputy CEO of the Power Public Corporation of Greece, responsible for Transmission and Distribution Networks and island DNO
- 2006-2014 - Chair of CIGRE SC C6 "Distribution Systems and Distributed Generation", convener of the strategic WG "Networks of the Future"
- Fellow Member of IEEE, former Chair of the Power System Dynamic Performance Committee
- Author of the book "Microgrids: Architectures and Control" and of more than 160 journal publications and 500 conference proceedings papers
- Partner in more than 50 EC RD&D projects, coordinator of the "Microgrids" and "More Microgrids" projects
- Ph.D., Electrical Engineering & Electronics, University of Manchester Institute of Science and Technology (UMIST), 1982
- M.Sc., Electrical Engineering & Electronics , University of Manchester Institute of Science and Technology (UMIST), 1979
- Diploma, Electrical and Mechanical Engineering, National Technical University of Athens, Greece, 1976

How does the ETP SmartGrids realise successful international cooperation on the European scale?

International collaboration at the European level is extremely important in order to successfully face the challenges of modern power systems - environmental, economic and security challenges. In this direction, the implementation of smart grids solutions is crucial, and the European countries have a lot to benefit from each other but also from other countries - the U.S., Japan, China, etc. Learning from successful projects, advanced technologies, national regulations and policies, societal initiatives, and others can effectively facilitate smart grids developments and help avoid mistakes. The ETP SG, comprising diverse stakeholders from many European countries and companies, plays a key role in the European networking with its close collaboration with national smart grids platforms, its connections with other European technology platforms, EERA (European Energy Research Alliance), ERA-NET SG+ initiative, national/regional smart grids funding agencies, its contribution to the European Technology Roadmaps and short- and long-term research priorities, and generally with its connections with the EC DG for Research and Innovation and the DG Energy.

"The most urgent issue is the specification of the priorities in the EU smart grids research and development in short and medium term."

How should stakeholders interact optimally to reach objectives?

The unique feature of the ETP SG is its diverse membership that ensures consolidated, unbiased views on the issues related to smart grids. In other words, the involved actors often have fundamentally different particular interests, but they are all characterised by their interest in the ETP SG, which is the unifying platform for the integration and system aspects of smart grids technologies. As a consequence, the ETP SG will continue to strengthen the integration of technologies, collaboration between stakeholders and between national interests. The formation of dedicated Working Groups (WGs), where high level experts representing various stakeholders liaise with each other, has proved to be a most efficient way to advance the work of the ETP SG.

Joint Technical Workshop of ELECTRA IRP and Working Group 1 of the ETP SmartGrids "Network Operation for 2030+" organised by DERlab, Brussels, 2014

What is the most urgent issue that the ETP SmartGrids is dealing with at the moment and by which means?

The most urgent issue is the specification of the priorities in the EU smart grids research and development in short and medium term. There are many systems aspects that still need to be resolved for the efficient integration of smart components, e.g., support is needed in distinguishing between storing, generating and consuming power with massive dispersed, volatile generation and flexible consumers with their own storage (electric vehicles), between power and energy (value of capacity versus value of energy), between regulated and market businesses (grid legislation and regulation, battery and generation investments and use), between the role of transmission and distribution, and others.

"DERlab plays a crucial role in developing and testing smart grid technologies."

How do you see the role and the impact of DERlab activities within the ETP SmartGrids?

DERlab, as an association of the main DER laboratories in Europe and its international connections, plays a crucial role in developing and testing smart grid technologies. One particular aspect where DERlab has already made an important impact is its contribution to standards. As an ETP SG facilitator, DERlab provides valuable support in organising, setting up, moderating workshops and drafting strategic ETP SG documents, thereby reducing complexity for the majority of involved smart grids stakeholders.

How can the ETP SmartGrids not only raise the awareness of the smart grids community but also that of the general public?

With the help of national/regional platforms, the ETP SG intends to promote the understanding of processes, lessons learned, perceived barriers and experiences by consumers and prosumers in pilot and demonstration projects, i.e., those who have had early experience in smart grids technologies. Moreover, the ETP SG publications have played a major role in the emergence of smart grids foundations in Europe and raising awareness of all stakeholders. It is our intention that they will continue to do so.

As the President of the ETP SmartGrids, can you tell us what strategic goals the ETP SmartGrids aims to achieve in 2015, and how will those complement prior activities?

In 2015 the strategic goal of the ETP SmartGrids is to support the EC in setting RDD goals and priorities in the upcoming Work Programme 2016/2017. This will be achieved by the ongoing efforts of the WGs, started in 2014, and by intensifying the cooperation with national smart grids platforms, in order to align ourselves with their national targets. The results of this work will be presented at the ETP SG General Assembly in April 2015. At the same time, the ETP SG aims to support the ERA-NET SG+ national and regional funding agencies in their efforts to create a strong bottom-up European network of national/regional funding agencies complementing the Horizon 2020 efforts of the European Commission.

What benefit and results can the smart grids community expect from the ETP SmartGrids?

The ETP SG encompasses almost all stakeholders of the smart grids community, such as operators, technology vendors, research and academia, associations, regulators, and others. Maintaining the strongest connections to the involved stakeholders at the top European level and via the national/regional platforms, the ETP SG is in a unique position to provide consolidated and unbiased views in all aspects related to the necessary R&D developments. It collectively possesses the highest level of technology expertise in all advanced frontiers of smart grids, i.e., technology for efficiency, security of supply and sustainability.

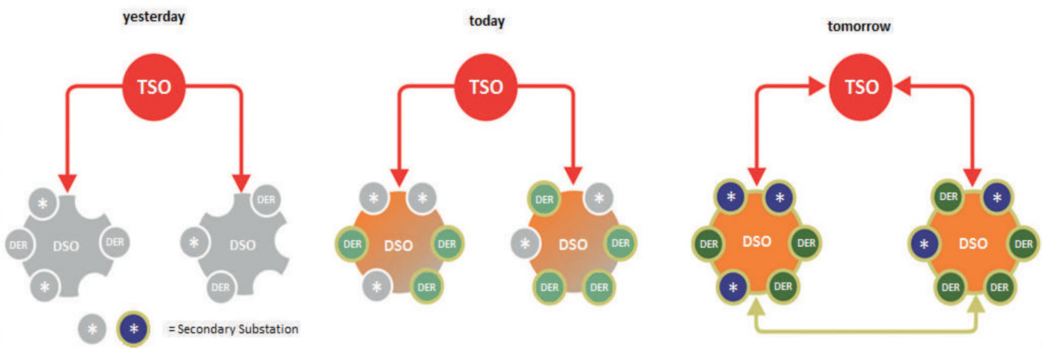
NETZ:KRAFT

DERlab supports grid restoration research in Germany

Info

NETZ:KRAFT: Grid restoration in consideration of future power plant structures (Netzwiederaufbau unter Berücksichtigung zukünftiger Kraftwerksstrukturen)
Duration: January 2015 - June 2018
Funding: Smart Electricity Grids funding initiative (Förderinitiative "Zukunftsfähige Stromnetze")
Partners: 21 project partners including DERlab and Fraunhofer IWES

In case of a blackout, transmission system operators are responsible for initiating the grid restoration process. This system service is currently mainly rendered by thermal power stations. With an increasing percentage of distributed energy resources in the grid, the application of the restoration process strategies faces certain challenges. The NETZ:KRAFT project aims to advance the development of existing processes and to define the role of renewable energy resources in the grid restoration process of the future.



NETZ:KRAFT presentation of the evolution of the grid restoration process

Source: Fraunhofer IWES

Power units with black start and island operation capability are two main requirements for the grid restoration process. In the current fleet of power stations in Germany, this role is taken over by thermal and hydraulic power units. In order to advance future changes, we need to reach two goals: the decrease in the number of thermal and hydraulic power units and the increase in the distribution grid generation. These factors make it more complicated to assess the behavior of the grid in a necessary restoration process. So, as a consequence of the increased renewable energy generation in Germany, it is necessary to reconsider the grid restoration process, which is the task of the newly launched NETZ:KRAFT project.

The two main goals of NETZ:KRAFT are:
1. Further development of the existing grid restoration processes at the transmission grid level, considering the increasing amount of distributed energy resources
2. Active usage of distributed energy resources in supply islands of distribution system operators to shorten the downtime of the grid.

The project begins with the definition of the current status of all processes, technical requirements and terms in the field of grid restoration and the definition of scenarios for case studies. The main part of the project works on reaching the two main project goals in parallel by developing technical requirements for the restoration process through case studies. These requirements will be tested in demonstrations. Finally, the project will coordinate the European collaboration and give recommendations for the grid restoration process.

DERlab supports the first steps of the project in the status determination of technology trends, terms and technical requirements of the grid restoration process as well as in the definition of the scenarios. DERlab also plays an important role in organising information exchange and the presentation of the project's recommendations on the European and international levels. The standardisation environment is another task DERlab is involved in: DERlab provides an overview of existing standards and standardisation activities for the grid restoration process and performs a review of those, especially considering the situation with high DER shares. The last task DERlab is caring for in NETZ:KRAFT concerns the presentation of the project recommendations on conferences and information exchange with other relevant platforms and initiatives.

NETZ:KRAFT kick-off meeting in Kassel (DE), January, 2015

Photo: Jürgen Hubert, DERlab

NOBEL GRID: Addressing all aspects of energy distribution and retail market

NOBEL GRID aims to develop, deploy and evaluate advanced tools and ICT services for distribution system operators (DSOs) and electric cooperatives, thus enabling active consumer involvement and market flexibility. Thus, this project also considers new demand response schemas and new business models for aggregators, energy service companies (ESCOs) and the integration of distributed renewable energy production.

Info

NOBEL GRID: New Cost-Efficient Business Models for Flexible Smart Grids
Duration: January 2015 - June 2018
Funding: Horizon 2020
Partners: 21 including DERlab

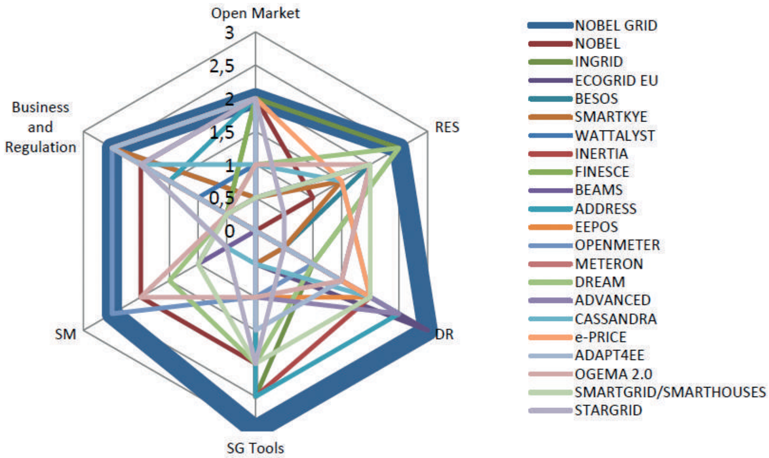
For further information please visit **www.nobelgrid.eu**

Through the dual-use of telecommunication networks and by validating the integration of distributed renewable generation and demand response systems, NOBEL GRID will offer advanced services not only for DSOs but to all actors in the distribution grid and retail electricity market in order to ensure that the consumers benefit from better prices, more secure and stable grids and the renewable electricity supply.

One of the first tasks of DERlab within the NOBEL GRID project is to carry out an analysis of energy policies and the regulatory framework on the energy markets at the national and global levels. In order to accelerate the market adoption of project solutions, they should be in line with current policies and regulatory frameworks. If they are not, it will be necessary to identify and propose the exact required modifications. Focus will be given to the related energy legislation and energy policies designed to deliver the 2020 targets and to shape energy market frameworks for 2030 and 2050.

Another important task DERlab undertakes is the definition of a standardisation map in the smart grid area. NOBEL GRID will identify, analyse and select the most suitable data models to be used in the context of the project realisation and will also identify potential contributions from the project results to relevant standardisation bodies. Since the main goal of the project is to define an open data model, NOBEL GRID will propose new solutions by taking into account the data models described by other European projects, e.g., STARGRID, in order to be aligned as much as possible with the state of the art, the standards, and the most common practices, and to bring innovations on top of this. The analysis and the definition of the data model will consider various current standardisation activities related to the integration of renewable energy resources (e.g., IEC 61850-7-420, EN 50438, CLC/FprTS 50549).

One of the unique elements of NOBEL GRID is the fact that it aims to satisfy the specific needs of cooperative and non-profit energy stakeholders. In addition, the very same solutions developed at NOBEL GRID will be easily transferable to any kind of energy stakeholder profile, including both small and large scale operators and marketers. Obviously from the engineering perspective, the challenge to be addressed will be the same, and so the tools defined by the project will be useful regardless of the organisational profile of the parties.



Source: ETRA

Above: NOBEL GRID position with regard to other European R&I activities
Below left: NOBEL GRID kick-off meeting in Valencia (ES) in January 2015

Photo: Mihai Calin, DERlab

The figure above shows clearly how NOBEL GRID complements the effort made by other projects, extending their results in the areas of open and competitive electricity markets, smart grid tools and technologies, smart metering systems, demand response, RES and new business models and regulatory framework.

Photo: TECNALIA

Research Infrastructure

Pre-standardisation Activities and Testing Facilities of DERlab



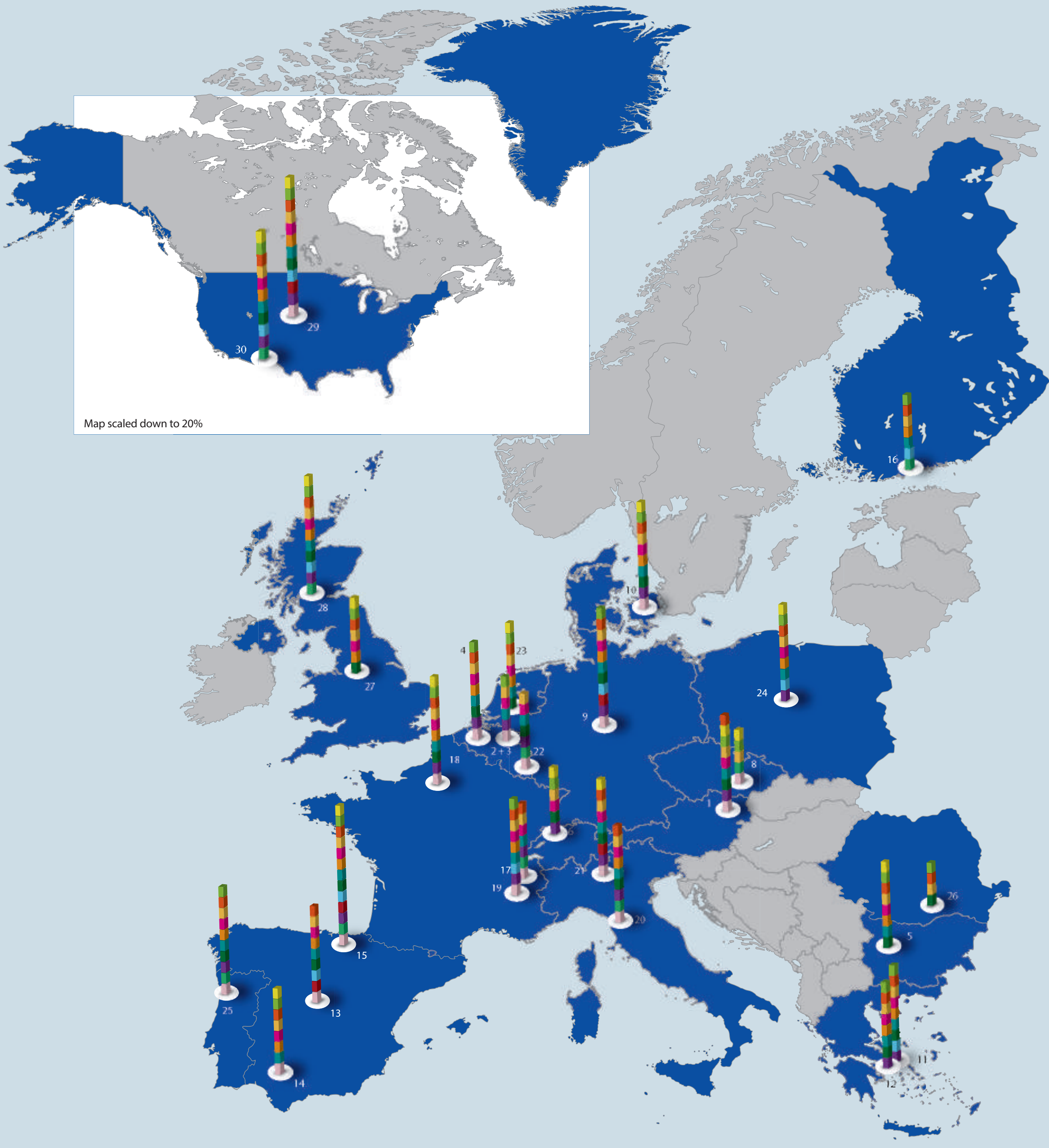

Research Infrastructure

	High Voltage & High Power	Power Quality & EMC	Hybrid Systems & Micro Grids	Power Electronics & Inverters	PV Systems	Wind Systems	Storage Systems	Comm. Tech. and Smart Metering	Fuel Cell Systems	Biomass Systems	Electric Vehicles	System Security and Reliability	Smart Buildings
1 AIT (AT)	●	●	●	●	●		●	●			●		●
2 & 3 EnergyVille (BE): VITO and KU Leuven		●		●	●		●				●		●
4 Lemcko (BE)		●	●	●	●	●	●	●			●		●
5 TUS-RDS (BG)	●	●	●	●	●	●	●	●					
6 HES-SO (CH)	●	●		●	●			●			●		
7 FOSS (CY)		●	●	●	●		●	●			●	●	●
8 CVVOZEPowerLab (CZ)	●	●		●								●	
9 IWES (DE)		●	●	●	●	●	●	●	●	●	●		●
10 DTU (DK)	●	●	●	●	●	●	●	●			●		●
11 CRES (EL)		●	●	●	●	●	●	●	●		●		
12 NTUA (EL)		●	●	●	●	●	●	●			●		
13 CIEMAT (ES)			●	●	●	●	●	●	●	●			●
14 EES-US group (ES)	●	●	●	●	●	●	●						●
15 TECNALIA (ES)	●	●	●	●	●	●	●	●	●	●	●	●	●
16 VTT (FI)		●	●	●		●	●		●			●	
17 CEA-INES (FR)			●	●	●		●				●	●	●
18 EDF (FR)	●	●	●	●	●	●	●	●			●		●
19 G2Elab (FR)		●	●	●	●	●	●		●		●		●
20 Enel (IT)			●	●	●	●	●	●			●	●	●
21 RSE (IT)	●		●	●	●		●	●		●	●		●
22 SnT (LU)				●	●		●	●			●	●	●
23 DNV GL (NL)	●	●	●	●	●	●	●	●					
24 TU Lodz (PL)	●	●	●	●	●	●	●		●		●		
25 INESC Porto (PT)		●	●	●	●	●	●	●			●	●	●
26 MicroDERlab Group (RO)		●	●	●				●					
27 University of Manchester (UK)	●	●	●	●	●	●		●					
28 University of Strathclyde (UK)	●	●	●	●	●	●	●	●	●		●	●	
29 NREL (US)	●	●	●	●	●	●	●	●	●	●	●		●
30 Sandia DETL (US)	●	●	●	●	●	●	●	●	●		●	●	

Research infrastructures of the member institutes of DERlab association cover the whole scope of distributed generation and smart grids

The transition towards high shares of renewable energy and the tendency to a more decentralised energy supply requires a smarter grid with sufficient hosting capacity and the ability to manage the power fluctuations of the renewable sources. High-level research and laboratory tests are vital to tackling these challenges. With the necessary expertise and capabilities, DERlab laboratories can carry out testing of individual components, such as DER converters or storage, as well as complete systems.

Futhermore, various effects that units have on the power systems can be verified in compliance with international and national standards or certification procedures.



DERlab member institutes as of February 2015

Towards Standardised HIL Experiments for Power System Testing

Georg Lauss, Felix Lehfuss, Thomas Strasser
(AIT Austrian Institute of Technology, Vienna, Austria)
Panos Kotsampopoulos, Vasilis Kleftakis, Nikos Hatziargyriou
(National Technical University of Athens, Athens, Greece)

DERlab members working together to harmonise and standardise HIL-based approaches to validate DER components and power system configurations

Current research in the domain of power distribution grids focuses on the operation of the grid with high penetration of Distributed Energy Resources (DERs). In particular, these DERs are Renewable Energy Sources (RES) from wind, solar or biomass, characterised by intermittent and only partially predictable production. In order to overcome the demanding challenges of power quality and grid stability given the great amount of variable production from renewables, it is necessary to make an extensive effort in controlling the power generators and/or the energy demand.

In recent years, advanced validation and testing methods have been in focus on the international level. A very promising approach is related to the real-time simulation and hardware-in-the-loop (HIL) experiments. The power-hardware-in-the-loop (PHIL) method has especially great potential to become a powerful validation technology for evaluating and testing the integration of DERs into active power distribution networks in a near real-world scenario [1]. In order to perform PHIL tests, it is necessary to have a powerful real-time simulation system (RTS) together with a power interface for the amplification of low-power signals to the power level of the DER components and proper measurement equipment (Figure 1).

DERlab members are actively involved in several activities in the improvement of the PHIL method (accuracy, stability, usability, etc.), development of the necessary hardware and software components as well as the modelling of DER devices in real-time environments.

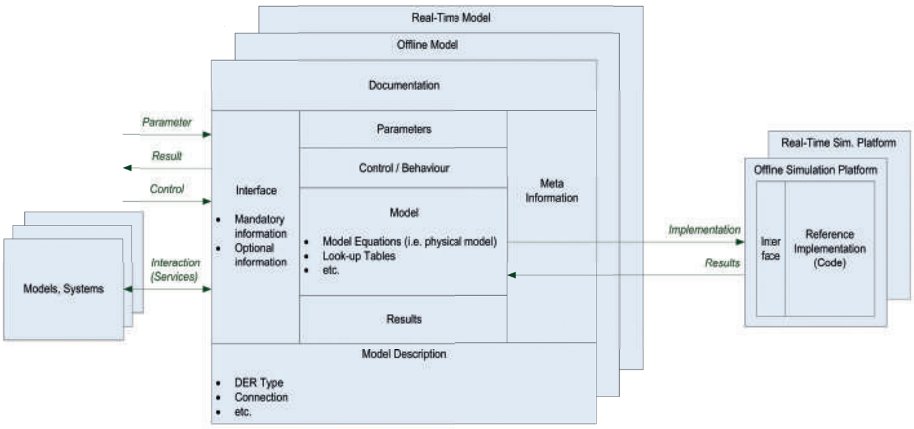


Figure 2: Main elements of the DERri Common Reference Model for DER Devices

Harmonised modelling of DER components: DERri Common Reference Model (CRM)

In the European FP7 project DERri, DERlab members have introduced an approach for harmonising the modelling of DER components, called Common Reference Model (CRM) [2], [3], [4]. The CRM contains a set of modelling rules for real-time HIL simulations and experiments. In parallel, the model provides an exchange format for the used DER components. The purpose of the CRM specification is to describe DER models in a representation independent from simulation environments, languages and tools, so it is easier to facilitate their sharing among different users. This allows an easier exchange and reuse of the DER models between different international laboratories (Figure 2).

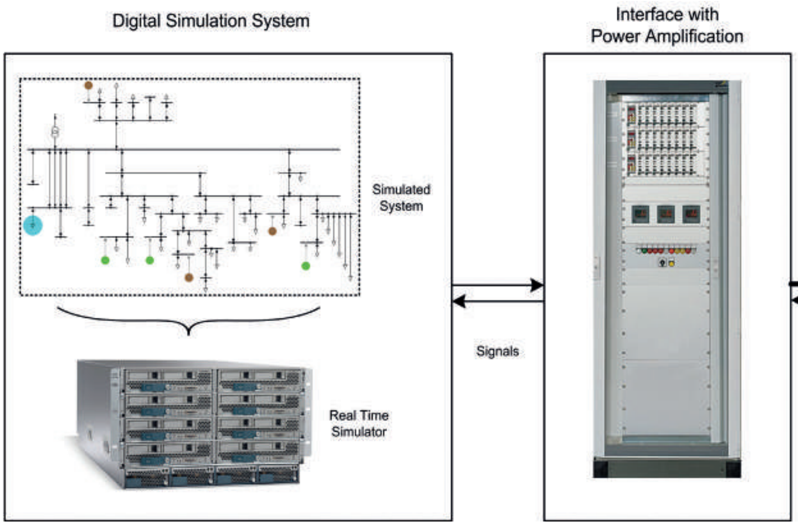


Figure 1: Sketch of a PHIL setup

International collaboration: IEEE Power and Energy Society Task Force on Real-Time Simulation of Power and Energy Systems

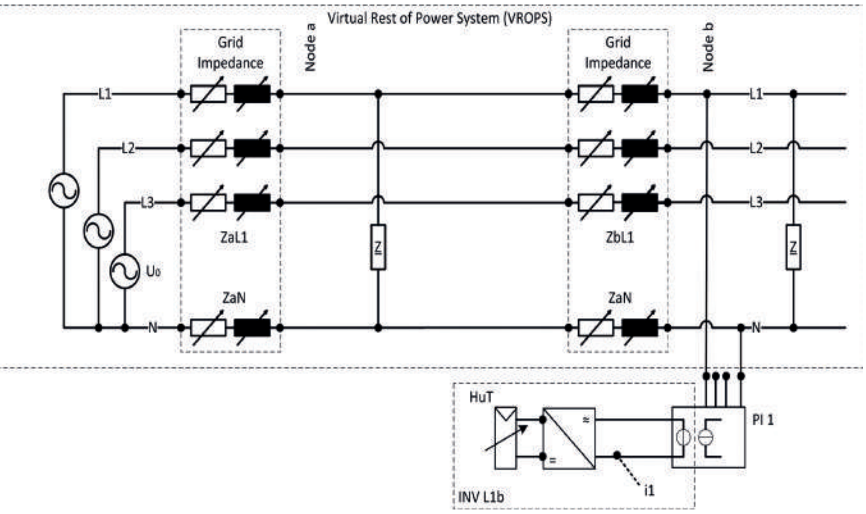


Figure 3: Example of a typical LV grid with integrated DER and implemented PHIL simulation setup

The topics of real-time simulation and HIL have been the focus of much international research and publication in recent years, this includes the IEEE PES Task Force. Active participation in discussions at international events and joint publications are significant results of this joint activity with active participation of several DERlab members. Within the Task Force on Real-Time Simulation of Power and Energy Systems, two major journal publications out of intended four are being coordinated and led by AIT and NTUA and can be seen as a continuation of [5], [6], [7], [8] and [9]. NTUA is leading a publication on a DER benchmark system for hardware-in-the-loop testing of distributed energy resources with a second paper being coordinated by AIT on the state-of-the-art evaluation of PHIL, titled "Characteristics and Design of Power-Hardware-in-Loop Simulations for Electrical Power Systems (Figure 3). AIT is the leader of the HIL subsection of this Task Force and is involved in all Task Force meetings, attracting new researchers to join the scientific discussion and contribution.

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HIL Testing and Field Applications of NTUA

An approach that is increasingly gaining interest at the international level is hardware-in-the-loop (HIL) simulation, where physical equipment is connected to a simulated system. The benefits of simulation (e.g., flexibility) and experimental testing (e.g., use of the real device) are combined in an environment that allows testing equipment under conditions very close to the real operating conditions.

The current testing practice considers two hardware-in-the-loop testing techniques:

- Controller-HIL: In a controller-hardware-in-the-loop (CHIL) simulation a hardware controller with its control algorithm is tested (e.g., converter controller, relay)
- Power-HIL: A physical power device is tested (e.g., PV inverter, wind energy system)

NTUA's research team is active in both categories of HIL testing.

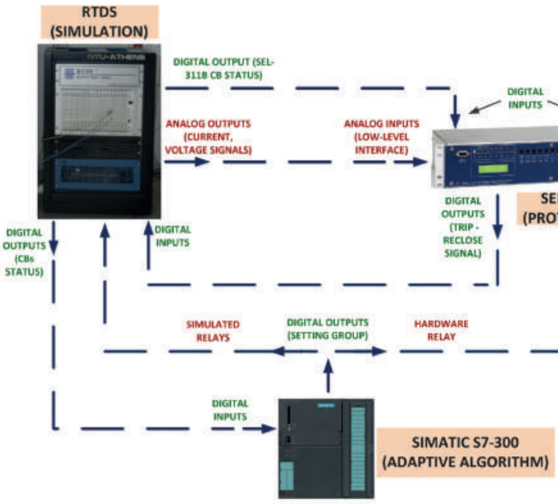


Figure 1: Adaptive protection scheme configuration

In the European FP7 project DERri, NTUA and other partners have made contributions to the pre-standardisation of PHIL tests. Several aspects of the PHIL setup have to be considered first in order to develop a standard procedure for PHIL tests. Requirements for the equipment (e.g., real-time simulator, power amplifier, sensor which measures the response of the hardware device) need to be defined as well as a standard laboratory procedure. Some basic laboratory procedures were included in these contributions as well as some schemes in the real-time simulator and the power interface.

For the CHIL tests, an adaptive protection architecture has been developed consisting of a Real Time Digital Simulator (RTDS®) of "RTDS Technologies Inc.", a multifunction digital relay SEL-311B of "Schweitzer Engineering Laboratories, Inc." and a SIMATIC S7-300 programmable logic controller (PLC) of "Siemens AG". The overall configuration is illustrated in Figure 1.

In the given implementation, the electrical networks are designed and studied in the real-time digital simulator (RTDS). The adaptive protection algorithm is implemented in SIMATIC S7-300 PLC (Programmable Logic Controller).

Meltemi: Community test site

Meltemi is a seaside resort located 15 km northeast of Athens. It consists of 170 cottages that are used as holiday resorts mostly during summer. The Meltemi camping site is a perfect living test field used by the Electric Energy Systems Laboratory of the NTUA. The field facility has been employed in a number of European and national R&D projects and studies regarding smart grids technologies. It has been used

Figure 2: Overview of the Meltemi Campus

Figure 4: Small wind turbine test site facilities of the NTUA

to validate methods of intelligent load management and increased use of RES. Tests have been performed to simulate emergency and critical grid situations where the site could balance its consumption with local generation. These tests have also simulated the provision of ancillary services to the upstream network including load shedding for system support during peak load.

The campus facilities comprise various distributed generators (DGs), including:

- 40kVA diesel generator
- small residential wind turbines
- 4.5 kW photovoltaic panels

A MultiAgent system (MAGIC) has been installed in a number of households allowing the DGs and the loads to negotiate in order to optimise energy production and consumption. The basic component of the MAGIC system is an intelligent load controller based on an embedded processor running on Linux and hosting Java based agents. This load controller can be used to monitor the status of a power line providing voltage, current and frequency measurements.

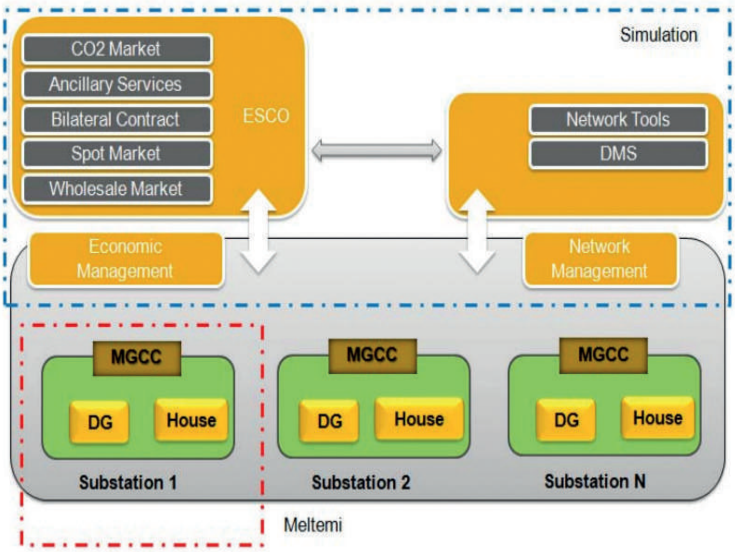


Figure 3: Overview of the agents on the Meltemi Campus

Within the campus a small wind turbine test site has been developed that allows outdoor measurements of the power and energy production of household small wind turbines for grid connected and battery charging applications.

- Testing of small wind turbines ranging from 1.2m to 7.6m rotor diameter
- The test site facilities comply with the IEC 61400121
- Logged data are stored locally and remotely on SmartRue data base in NTUA
- Data management tool allows in-depth analysis of the measurements

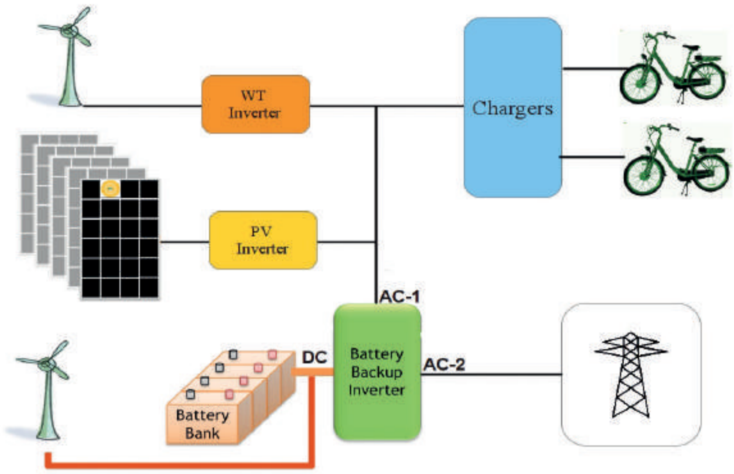


Figure 5: The e-bike charge station setup

Ongoing projects include the design and installation of an e-bike sharing system.

- Stations with automated self-serve docking charging systems are located at key places within the camp
- The station uses energy from RES and a battery bank (of 150Ah) for recharging electric bicycles.
- Also available is the backup supply by the utility power grid via a DC/AC battery inverter
- The stations are able to work in various modes, both island and grid connected and to accomplish zero net energy consumption

Extended DER testing capabilities at Fraunhofer IWES

Batteries, CHP units, utility-scale PV installations, and their integration into the distribution grids are attracting increasing attention. Testing needs for these components and systems are constantly expanding. Fraunhofer IWES made an extensive effort to adapt its Test Center for Smart Grids and E-Mobility SysTec to the increased requirements.

CHP: grid interface compliance testing

In Germany, the certification of the dynamic voltage support from CHP units connected to medium voltage became mandatory in 2014. Fraunhofer IWES is supporting these activities with contributions to the working group elaborating the testing procedures (FGW TR4 VKM) and with the setting up of a test bench for testing the grid interface of CHP units up to 2.5 MW (thermal power).

CHP grid interface test bench at the Fraunhofer IWES SysTec with a thermal rating of up to 2.5 MW

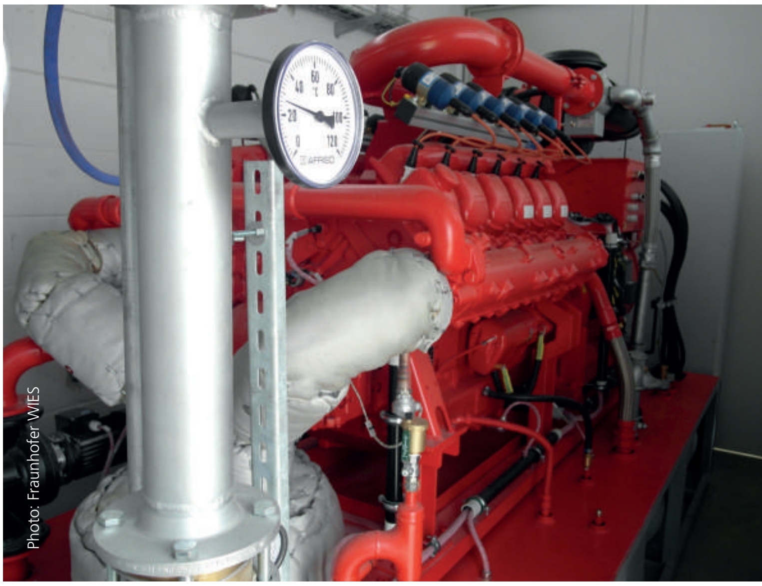


Photo: Fraunhofer WIES

High power DC source for testing of PV inverters

The global market outlook for utility-scale PV installations is very positive and central inverters will take their share. Therefore, the capabilities for the development accompanying and grid compliance testing were expanded, and the rating of the DC source was increased to 3 MW. Besides inverter testing, it can also be used for testing of other DC-fed resources, e.g., fuel cells.

The high power DC source in SysTec comprises 14 power modules (5 x 150 kW, 9 x 250 kW). The modules can be flexibly interconnected in configurations up to 3000 A at 1000 V or up to voltages of 4 kV.

Test grids for the investigation of new grid operation strategies and interoperability (MV and LV)

For the investigation of grid sectors with high shares of renewables, new grid operation strategies, interoperability of components, and automatic control approaches, grid sections for MV (20 kV) and LV (400 V) are set up in the hardware of the SysTec outdoor area.

The LV grid section consists of five cables with different diameters. The interconnection of the LV cables can be flexibly configured setting up different LV grid conditions. Two bus bars for the interconnection of DER (e.g., batteries, a diesel generator set) are installed and connected via a MV/LV substation to corresponding MV grid sections of which one is equipped with an OLTC transformer. A cable line of about 400 m and/or hardware line emulation can be used to connect these MV grid sections.

PHiL/storage system test bench at the Fraunhofer IWES SysTec

Power-Hardware-in-the-Loop and the storage system test bench

For storage system testing and the development of e-mobility applications in particular, SysTec set up a test bench comprising programmable inverters, a virtual battery (a power electronics-based battery simulation system) and a network simulator for dynamic testing.

The test bench or its respective parts can also be used for power-hardware-in-the-loop (PHIL) testing.

Power Amplifier	
Model	AC-Grid simulator RS270 3~
Power	3x90 kVA (3~) 1x270 kVA (3~)
Frequency	16 Hz – 819 Hz
Voltage	max 465 V_{LN}
Currents	max 600 A per phase (lower voltage)

On the right of the PHIL test bench picture above, you can see three 3-phase power amplifiers from Ametek with 270kVA in total. The amplifier can be used as a sink or a source. Opposite you can see a DC-source from Scienlab (sink-source operation), which can be replaced by real distributed energy resources like solar panels, wind turbines or combined heat and power plants. On the left side is the programmable and flexible inverter from TriPhase with up to 5 kVA each for implementing own control algorithms and testing support strategies for the power system during stability issues.

DC Source	
Model	SL850/600/120BE1C
Power	120 kW
Voltage	max 850 V
Currents	Max ±600 A

In an upcoming project, the system will be integrated in a real-time system for power system stability analyses using it as a multi-terminal power-hardware-in-the-loop test bench.

Fraunhofer IWES

Grid compliance validation extending to advanced inverter functions for large-scale inverters at DNV GL

At DNV GL the validation of grid compliance of large-scale inverters, performed in the Flex Power Grid Lab, now also covers the range of advanced inverter functions that are slowly but surely making their way into more and more large-scale inverter control systems. This follows on from the rapid developments in power systems, which have revealed that with a large share of DER in power systems the DER now needs to actively contribute to stable and reliable power system operation. As an immediate consequence, the testing and validation of individual components for grid compliance will no longer suffice on its own. Therefore, in order to de-risk and ultimately certify equipment in complex power systems under dynamic situations - whilst simultaneously taking into account the advanced functionality offered by the individual inverters - the corresponding validation tests used for ascertaining grid compliance now also take into account the entire power system and its dynamic behavior in all of its facets. This is off course a feat not easily achieved considering the scale of power grids in relation to the DER equipment tested, not to mention the impact on the research and testing infrastructure performing the test and the certification.

For this reason, the combination of (digital) simulation together with physical hardware experimentation will become inevitable to allow the validation and later certification of the system at the required complexity including the highly dynamic and transient power system behavior under real-time constraints, whilst keeping the economics of performing the actual test realistic. Fortunately within DERlab and also more recently within the ISGAN SIRFN, the use of advanced testing techniques towards power system verification, including co-simulation, control- and power-hardware-in-the-loop, has matured and taken a more prominent position as extension of the standard research and testing methods available within the network of DERlab research infrastructures. Also worth mentioning are the advances made in standardising the communication with inverters to command the advanced inverter functions, described in the IEC61850 and implemented through, for example, the SunSpec Alliance.

Installation of a power transformer at DNV GL

From DNV GL's perspective, these advanced testing methods used together with sophisticated laboratory infrastructure are key to ensuring the safe and reliable operation of power systems in onshore, offshore and island grids in the future. DNV GL's dedication is emphasised further by the recent acquisition of Marine Cybernetics - a Norwegian based company (Trondheim) - specialising in the testing and validation of advanced control systems using exclusively hardware-in-the-loop methods.

DNV·GL

Small Wind Turbines Pre-standardisation at CIEMAT

Ciemat

Deployed in urban and rural areas as distributed generation systems connected to the main power grid, small wind turbines (SWTs) help to reduce the amount of expensive electricity purchased or take advantage of the new tariffs already applied in some European countries, the U.S. and Japan for domestic micro-generation. This application has raised the issue of quality assurance as one of the most important ones in the development of the SWT sector: due to the proximity to users, aspects like safety or acoustic noise have become extremely important.

CIEMAT is a co-convenor of the new standard IEC 61400-2 3rd edition "Safety of small wind turbines" issued in December 2013. This standard deals with safety philosophy, quality assurance, and engineering integrity and specifies requirements for the safety of SWTs including design, installation, maintenance and operation under specified external conditions.

As the Operating Agent of the International Energy Agency IEA Wind Implementing Agreement Task, CIEMAT is also involved in identifying new issues to the application of SWTs in the urban and peri-urban environment and special wind conditions (e.g., high turbulence). Some of the expected results of Task 27 are:

- Deployment of a consumer label for SWT
- Development of a Recommended Practice that provides guidelines and information on micro-siting of small turbines in highly turbulent sites
- Preparation for standards by developing a new approach to Vertical Axis SWTs by means of a preliminary Simplified Loads Methodology (SLM) for different technologies, and refining the already existing Horizontal Axis SLM

Finally within the framework of IEC in January 2013, the Conformity Assessment Board CAB Wind Turbine Certification Committee (WT CAC) decided to form a separate subgroup to consider Conformity Assessment Matters as they relate to the SWT industry. With the CIEMAT participation, this group together with the SWAT (Small Wind Association of Testers) has the objective to improve the overall quality of SWT testing and work towards the harmonisation in the interpretation and application of wind turbine testing standards.

Testing facilities and capabilities

CIEMAT has SWT installations on four SWT sites (Spanish acronym - PEPAs) in Soria in order to be able to cope with most of the existing classes (as defined in EN 61400-2), ranges (5 – 15 – 100 kW) and applications (grid connected, battery charging, pumping). There are 18 testing positions in different wind resources as some of them are up in the mountains on CLASS I and II sites. The existing SWT sites allow the performance of the following accredited tests:

- Power curve test (according to EN 61400 12-1)
- Duration test (according to EN 61400-2)
- Safety and operation tests (according to EN 61400-2)
- Acoustic noise emissions tests (according to EN 61400-11)
- Static and dynamic blade tests (according to EN 61400-23)

For battery connected tests of SWTs, there are lead-acid battery banks available, ranging from 24V up to 300V. For blade tests, there is a new blade test rig, with the capability to perform tests in blades up to 11 meters length. With this facility, both static and dynamic (fatigue) blade tests can be carried out.

Generators used in SWTs have also been tested in CIEMAT with a generator test rig according to the EN-60034 standard. This test rig is to be substituted by a new improved generator test facility allowing testing generators up to 100 kW.

CIEMAT SWT testing site in Soria (ES)

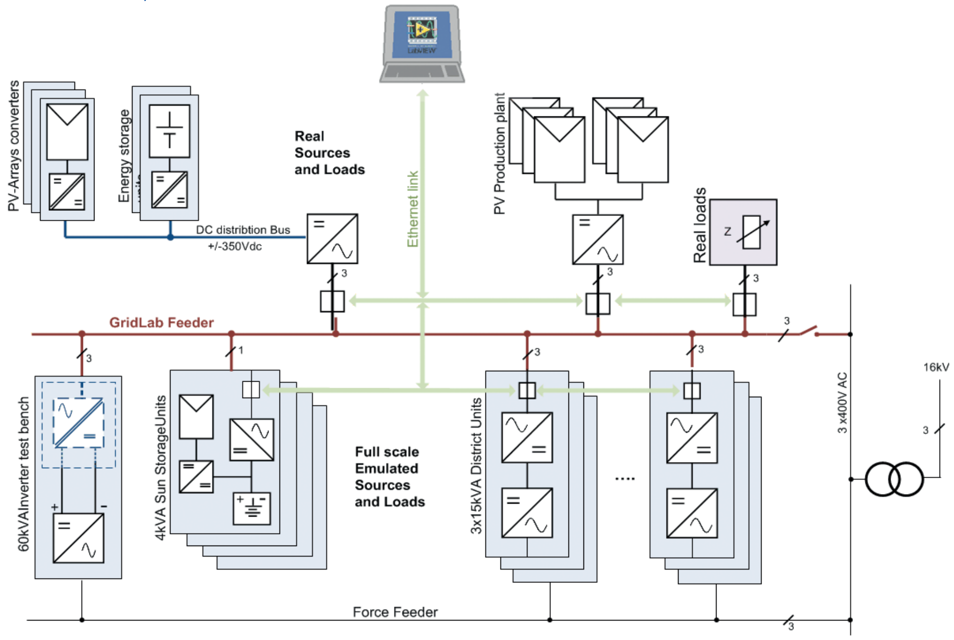

Photo: CIEMAT

Pre-standardisation Activities in Grid Integration of DER at GridLab HEI-VS

at the HES-SO University of Applied Sciences and Arts of Western Switzerland

Grid Lab at the HEI-VS

GridLab LV, bloc scheme



the role of a consumer or producer according to the programmed running scenarios. The active and reactive power absorbed or fed by each individual unit can also be controlled locally or centrally.

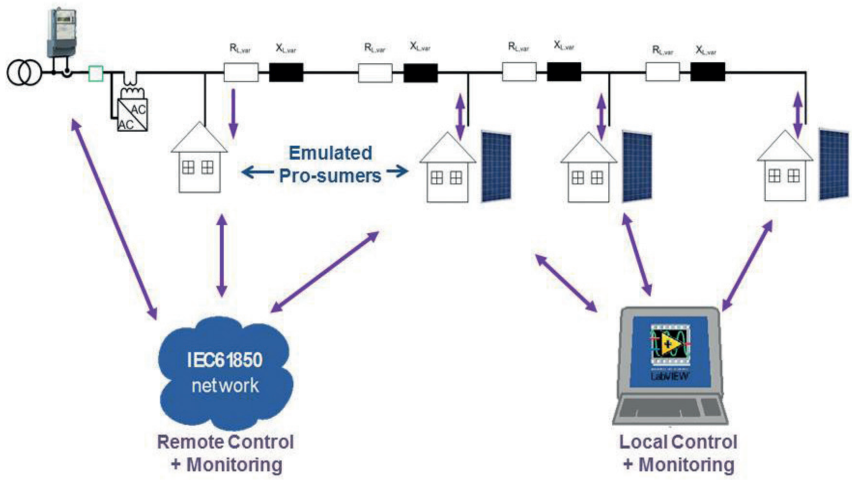
The impact of DER on power quality in the LV distribution grid can be assessed in the most realistic conditions achievable in an indoor laboratory infrastructure. New strategies and actions for improvement of power quality, like voltage stability or EMC, can be evaluated or improved at a system level. The GridLab LV platform is completed with a state-of-the-art inverter test bed. A PV inverter up to 30kW can be tested in terms of efficiency and EMC emissions.

The GridLab Low Voltage located at the HES-SO University of Applied Sciences and Arts of Western Switzerland, is a full scale experimentation platform dedicated to research and teaching activities in the field of renewable energy resources and storage integration into the grid. At the heart of the GridLab LV is a 3-phase 400Vac feeder with connected loads and sources. For better efficiency and increased flexibility, prosumer's loads, production and storage systems are emulated with the help of static converters.
The state-of-the-art communication infrastructure allows data exchange between converters and a centralised control unit. Real loads, storage units and a photovoltaic power plant complete the GridLab LV for a systemic representation of DER integration to the grid.

Year 2014 has been rich in activities with the completion of three district units, including nine bi-directional 3-phase converters for a total installed power of ca. 150kW. The converters are connected to a common point of coupling through overhead lines or cables emulated with passive components. Each converter can emulate a family house taking

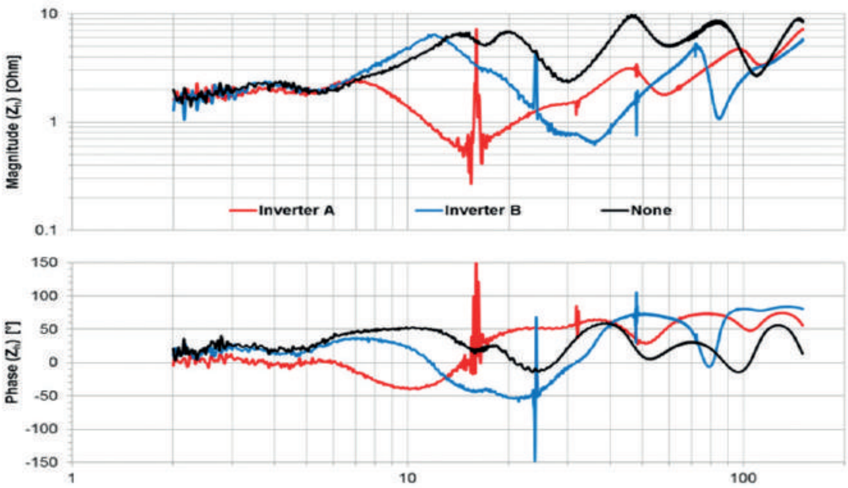
ICT is taking a leading role in the realisation of smart grids. Several research projects based on the IEC 61850-90-7 Communication networks and systems for power utility automation are under way: object models for power converters in distributed energy resources (DER) systems could already make use of the GridLab infrastructure.

Control of a district unit



Pre-standardisation EMC activities at GridLab LV

For several years an important part of our research activities has been dedicated to Electromagnetic Compatibility (EMC) issues in the case of the massive penetration of Distributed Energy Resources and storage. Special attention is currently being paid to the EM interference between electronic equipment connected to the grid and Mains Communication Systems (MCS) dedicated to the controlling and the monitoring of LV distribution network and the energy usage of connected equipment and premises. Due to the increasing number of power electronic converters directly connected to the LV, including PV inverters, EV battery chargers, UPS, drives, more and more interference cases with MCS in the frequency range between 9 and 150 kHz are being reported. The EMC standardisation committees are facing a very complex situation with a conflict of interests of different industrial sectors.



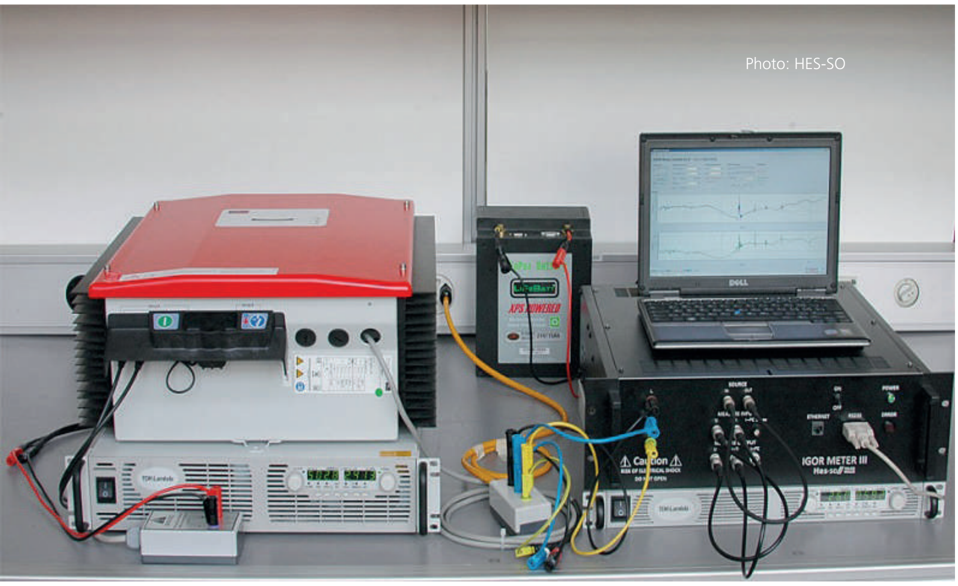


Photo: HES-SO

Based on a frequency model of sources, loads, filters, lines and transformers, a systematic approach is deployed at GridLab LV. The spectral grid impedance seen from different points of coupling at different times of the day can help to establish such a model. In this context, a spectral grid impedance meter with a frequency range between 2 and 200 kHz has been designed and tested at the GridLab LV.

Grid Lab

Hes·so VALAIS WALLIS
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences Western Switzerland

FOSS Pre-standardisation Research Activities

The Research Centre for Sustainable Energy (FOSS) was created in 2013 to play a key role in research and technological development activities in the field of sustainable energy within Cyprus, at the regional and international levels. The aim is to contribute to achieving energy and environment objectives set out by the European nations. The FOSS assembles significant research expertise from the University of Cyprus and industry in a wide range of fields: electrical, mechanical, civil, environmental, chemical engineering, physics, chemistry, economics, finance, and architecture. In particular, the FOSS strives to build on its long experience and valuable research work in photovoltaic (PV) technologies and become a centre of excellence in sustainable energy, capable of delivering world-class R&D work offering measurable scientific value, training activities, and technological innovation.

Members of the Centre represent Cyprus in European Energy Committees, such as the Energy Committee for the Horizon 2020, the International Energy Agency (IEA), the SET Plan, the Solar Energy Industrial Initiative, the European Smart Grid and PV Technology Platforms, the European Standards Committees on PV and the EU PV Platform Mirror Group.

Pre-standardisation Research Activities

Smart electricity networks

• Demand side management: modelling and simulating demand response in order to implement dynamic tariffs

• Energy forecasting: development of reliable energy forecasting tools for the day and one hour ahead of PV energy production, taking account of cloud spatial variability and the ramping effects of the produced power

• Power line communications (PLC): the assessment of the performance and effectiveness of PLC technologies over low and medium voltage grid networks

Integrated solutions

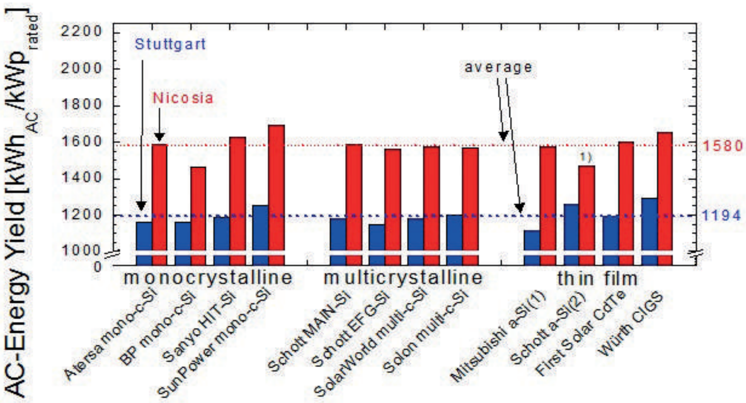
• Integrated control strategies for distribution systems: research on control algorithms for the integration of renewable energy sources (RES) technologies in existing grids and the use of energy storage systems (ESS) to smoothen the power generation of RES technologies

• Micro-grids: development of simulation models for the operation and performance of microgrids

• Electric mobility: modelling of low-power electric vehicles and vehicle-to-grid (V2G) and grid-to-vehicle (G2V) strategies for grid stabilisation and optimal use

RES

• Outdoor PV performance: outdoor performance assessment of innovative PV devices at the cell, module, and system levels. Research in this area focuses on investigating the real performance of different PV technologies, accurate energy yield predictions of PV systems, optimisation of the yield of PV systems and the development of special module packaging designs for better heat dissipation.



• PV applications: mini-grids, transportation and building integrated PV (BIPV) and applied PV (BAPV) applications

• PV performance modelling: gaining a deep understanding in the field of PV system energy production, ageing and degradation (modelling degradation rates) as well as spectral simulation and spatial cloud coverage influences. This research area also includes the development of failure detection algorithms in real PV systems and the modelling

Outdoor PV test facility

of new degradation modes in PV, such as potential induced degradation (PID)

• Standardisation and characterisation: development of models and characterisation of new PV cell technologies and concentrating PV (CPV) both indoors and outdoors.

Infrastructure and Equipment

The FOSS Research Centre for Sustainable Energy performs pre-standardisation research with two of its principle laboratories:

PV Technology Laboratory
www.pvtechnology.ucy.ac.cy

The PV Technology Laboratory comprises a state-of-the-art indoor infrastructure for PV research at the cells, modules, and systems levels.

Power System Modelling Laboratory
www.psm.ucy.ac.cy

The Power System Modelling (PSM) Laboratory performs high quality research in the following areas: electrical control and analysis of DC corrosion, engineering cost-benefit analysis and risk management for R.E., earthing and lightning protection, solar applications and LV systems. It benefits from state-of-the-art software tools that are either commercially available or developed in-house.

More specifically, the outdoor facilities of the centre consist of diagnostic equipment for the measurement and monitoring, at high resolution, of all the important environmental and operational parameters of PV systems, including the light spectrum on an accurate dual axis tracker and at the plane of array. All the installed sensors, data acquisition and monitoring equipment comply with the accuracy requirements of the IEC 61724 standard. Currently, more than 25 grid connected PV systems of different technologies, each one having a nominal power of ~1 kWp, are monitored and connected to the central data acquisition system. The PV technologies are installed outdoors both on fixed and tracked mounting setups and include mono-crystalline, poly-crystalline and amorphous silicon, cadmium telluride (CdTe), copper indium gallium diselenide (CIGS) and other high efficiency solar cell technologies from a range of manufacturers, including TSMC, Honeywell, Oerlikon, Schott Solar, T-Solar, Q-Cells, BP Solar, Sanyo, SunPower and others. Active tracking systems are also equipped with the latest technologies, covering the majority of the current and up-and-coming PV technologies. Furthermore, the outdoor equipment includes grid-connected programmable inverters, module current-voltage curve tracing loads, maximum power point trackers, along with a newly developed PID setup for accelerated degradation tests and material insulation tests.

The facility further includes stand-alone systems for storage and vehicle charging connected to data acquisition devices to monitor important performance parameters related to the field of electric mobility.

The indoor facilities consist of an environmental chamber, a solar simulator, a UV chamber, thermal and electroluminescence imaging apparatus, cell and lens characterisation systems and spectral response measuring equipment. Along with research usage, the indoor equipment is suitable for standardised and non-standardised indoor tests based on the requirements of IEC 61215 and IEC 61646. It also enables accurate degradation studies of different PV technologies including accelerated aging investigation, correlation of indoor-outdoor degradation effects and new degradation effects studies such as PID. The environmental chamber can be used for durability and exposure tests of material and devices (modules and batteries) at different thermal and humidity exposure cycles.

In addition, the centre also administrates a distributed network of 30 pilot plants installed in Cyprus, each being a domestic customer with an installed smart meter, meteorological station and PV system. The pilot plants are used in order to acquire real data sets of the production and consumption profiles with the goal of optimising smart energy management systems and tariffing schemes. The acquired data sets are stored on the central database servers maintained by the personnel of the FOSS and in close collaboration with the Electricity Authority of Cyprus.

Furthermore, the centre operates a Broadband over Power Line (BPL) facility with the support of industry technology leader Corinex Communications. The facility is equipped with the latest in Corinex BPL-to-the-meter technology, with facilities for testing and validating BPL communications performance on LV and MV lines utilising bi-directional data from smart meters installed at the laboratory.

Finally, the FOSS also benefits from state-of-the-art specialised software tools that enable the interface between the commercially available Real Time Digital Simulator RTDS® and Multi Agent Control Systems that optimise the combined integration of PV systems and battery storage. Additional software tools are continuously upgraded with software packages to ensure meeting the mandates assigned to each research area: Matlab, Comsol, PSCAD, Digsilend, PowerWorld, PSPICE, PVSyst, RETScreen, ProfiSignal, Loggernet, AutoCAD, Agilent, and others.

Indoor PV test facility

Photo: FOSS

FOSS
Research Centre for
Sustainable Energy

www.foss.ucy.ac.cy

Photo: EU PVSEC 2014

European PV Solar Energy
Conference and Exhibition

www.photovoltaic-conference.com

At the 29th European PV Solar Energy Conference and Exhibition (EU PVSEC), a research team from the FOSS Research Centre of Sustainable Energy of the University of Cyprus (UCY) has won the top prize. The paper titled "Robust Principal Component Analysis for Computing the Degradation Rates of Different Photovoltaic Systems" by Andreas Kyprianou, Alexander Phinikarides, George Makrides and George E. Georghiou has won the best visual presentation award in the field of Operations, Performance and Reliability of Photovoltaics.

Evaluation of the impact on power quality of hybrid generators and hybrid buses

Power Networks Demonstration Centre at the University of Strathclyde

The Power Networks Demonstration Centre (PNDC) was fully commissioned in February 2014, and since then a number of important projects have been completed using the advanced PNDC distribution network.

One area of work has been the performance evaluation of different prototype hybrid generators. The hybrid generators tested contain a diesel generator and a power-electronic converter interfaced battery. The tested units are late stage prototypes and will be deployed on the public distribution network after they have been tested for operational readiness at the PNDC.

The hybrid generators have been connected to the PNDC HV and LV distribution network and tested for several performance criteria including: fuel efficiency and power quality over a typical 24-hour residential load profile, maximum power output capability, protection settings and operation, and battery charge/discharge times.

The unique nature of PNDC and its testing regime is such that the team can identify potential operational improvements to devices and their interfaces and by collaborating with the manufacturer support rapid resolution and enhancement.

A similar area of work has been the investigation of the impact of induction chargers for hybrid buses on the distribution network power quality.

One such induction charger has been installed at the PNDC and connected to the PNDC distribution network. Voltage and current on the distribution system were recorded with calibrated equipment to measure harmonic content, allowing

An aerial picture of the PNDC HV compound during the testing of trailer and truck mounted hybrid generators

the assessment of the impact of induction chargers at the point of connection and at different locations into the network. Performance and operational processes can be appraised using the on-route charging facility, which supports the assessment of a wide range of manufacturing, integration and operating options.

UNIVERSITY of STRATHCLYDE
POWER NETWORKS
DEMONSTRATION CENTRE

"Having the capacity to scrutinise, evaluate and quantify the performance of what we have developed from an objective but impartial perspective has been invaluable. The facilities and technical expertise that PNDC offers are very impressive and have enabled rigorous testing and evaluation of the feedback by which means we have produced a fully rounded and proven solution for our client. What we have gained as a result has progressed our understanding of the technology and extended our research beyond what would have been possible otherwise. What is more, the relationships we have evolved have been great where we have been able to benefit from an academic perspective that goes beyond the work in hand; we really feel as though the team at PNDC have been engaged with the journey, and their contribution has been very welcome."

- Quote from a hybrid generator manufacturer

Battery storage testing and services in the VITO unit Energy Technology

The VITO unit Energy Technology focuses on smart grids and its core aspect - storage. Apart from having a laboratory for battery tests and providing system integration services, VITO offers the following unique facilities and services.

Public tool for battery standards and system integration

The publicly available tool (batterystandards.vito.be) comprises standards that cover batteries and system integration with batteries including grid connection, PV installations, converters and EV charging. Approximately 400 standards available in the tool refer to test conditions or specific component requirements as well as standards on safety design in general, like the FMEA (IEC/EN 60812), or the safety of machinery (ISO Guide 78). Including not only international standards (IEC, ISO, UL) but also country specific ones (DIN, SAE, ZVEI, etc.), the tool aims to facilitate system integration.

Figure 1 (left): The battery standards tool

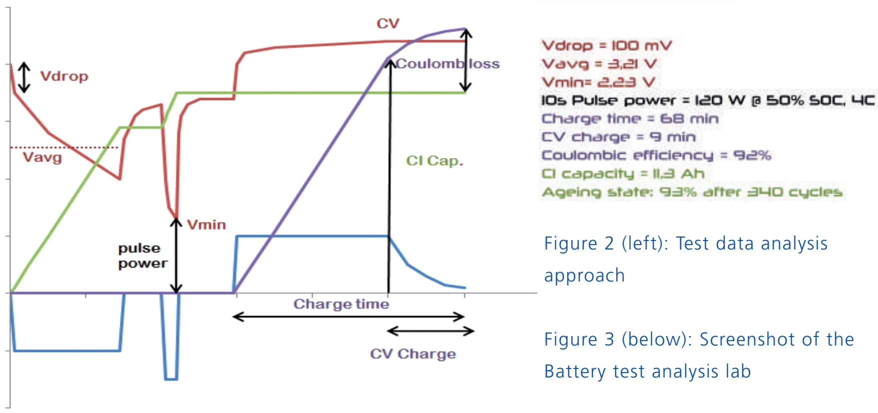
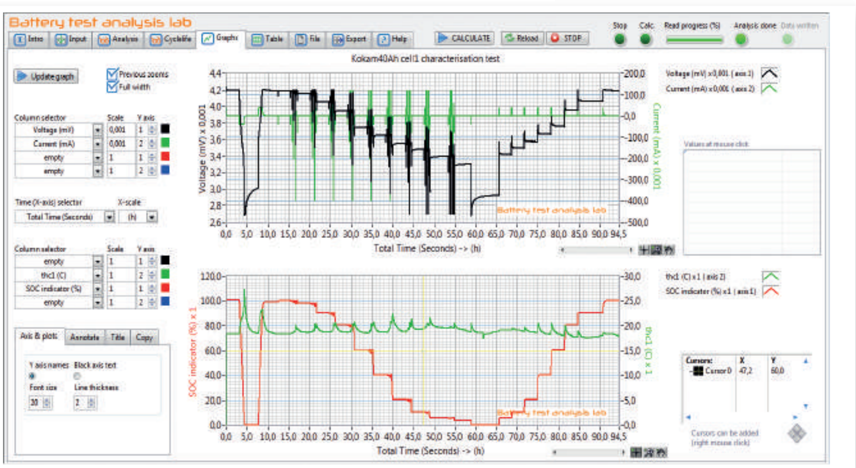


Figure 2 (left): Test data analysis approach

Figure 3 (below): Screenshot of the Battery test analysis lab



Battery test analysis tools for rent and purchase

Analysing battery tests is a tedious task - scrolling through long data tables, gazing at graphs, making tables to follow up battery ageing. VITO-ETE developed a software that radically changes the laboratory approach: type in what you want to know and let the software search for every instance in the data. It also works if you need intermediate calculations. If you want to obtain, for example, 1s peak power, 30s pulse resistance, average discharge voltage, the charge level at reaching CV charging, just the battery capacity, coulomb efficiency or battery ageing without copying data sets to Excel or similar, look at battery test data in this new way (Figure 2). The software has six main functions:

- battery test data analysis with the help of a script file
- possibility to search for specific data in the test data table
- life cycle test data analysis, also with a script file
- certain sections of the data can be exported for other users with the interpolation possibility
- ability to visualise the data in graphs (Figure 3)
- exporting to Excel

Five modules available to date:

- Battery test analysis lab
- Battery modelling lab
- C-rate plot lab
- GITT-like discharge plot lab
- Multi-life analysis lab

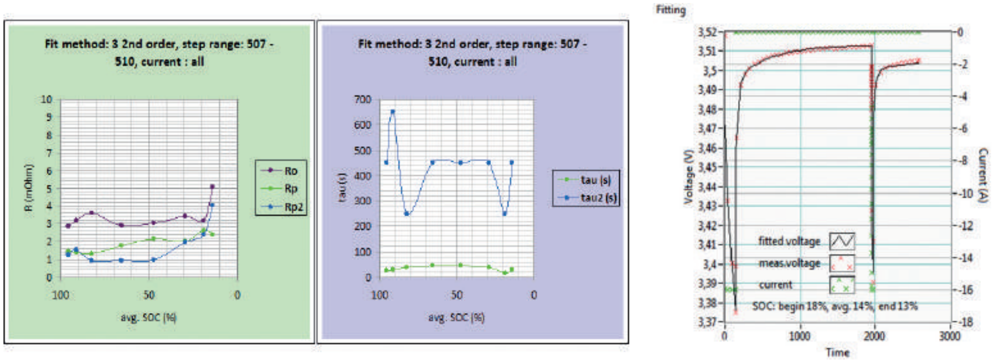


Figure 4 (above): Battery model parameters and a fit exported to Excel.

The Battery modelling lab enables the easy fitting of the measurement data in battery models. The Thévenin-model and the FreedomCar model are available in 0th, 1st and 2nd order. The fit data and the fits themselves are automatically exported to Excel. Choosing between orders and resolution in SOC levels becomes easy, with some results shown in Figure 4.

Advanced battery characterisation methodology

VITO developed a unique approach to characterise cells based on:

- capacity at several C-rates
- Peukert phenomenon, heating behaviour, cell resistance
- pulse powers, pulse efficiencies, pulse resistances, battery modelling
- hysteresis of OCV curves, relaxation of OCV

The test results can be compared with many other cells (see Figure 5). The test allows model parameterisation as in the previous section, hysteresis of OCV curves and the relaxation of OCV.

Solar batteries tests for grid connected dwellings

Typical of households:

- The existence of a small base load caused by, e.g., a refrigerator.
- Many appliances with an on-off regulation, such as a microwave and cooking hobs (e.g., 15s on, 30s off)
- The charge is often spiky at low power due to cloudy conditions

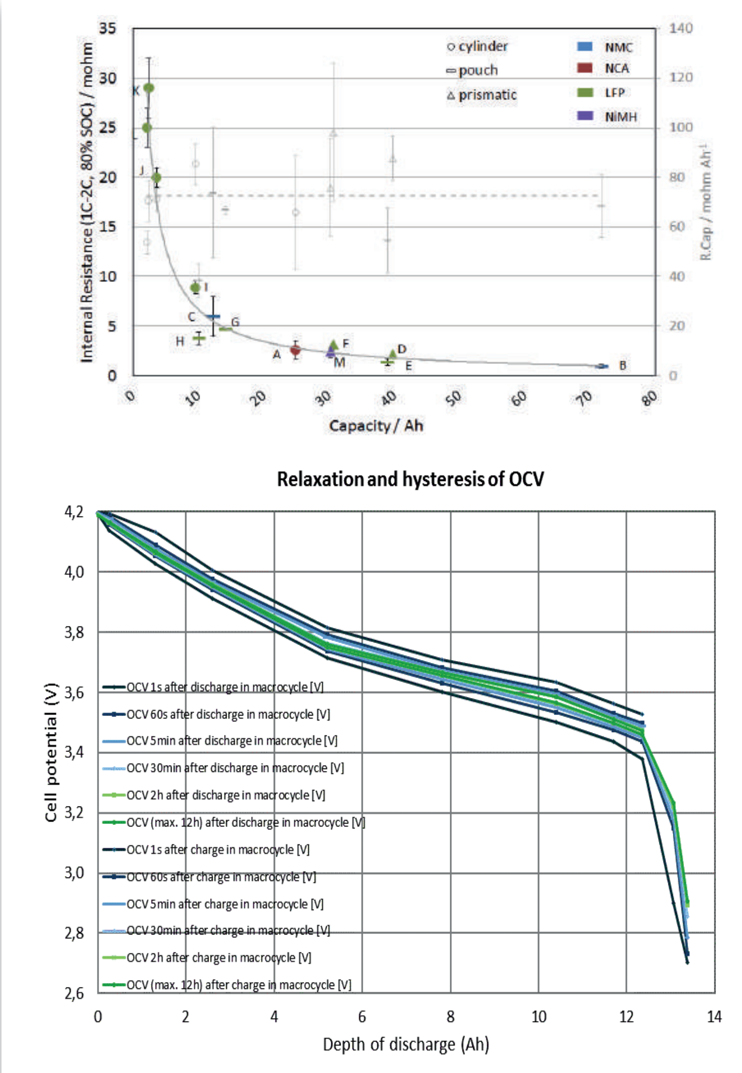
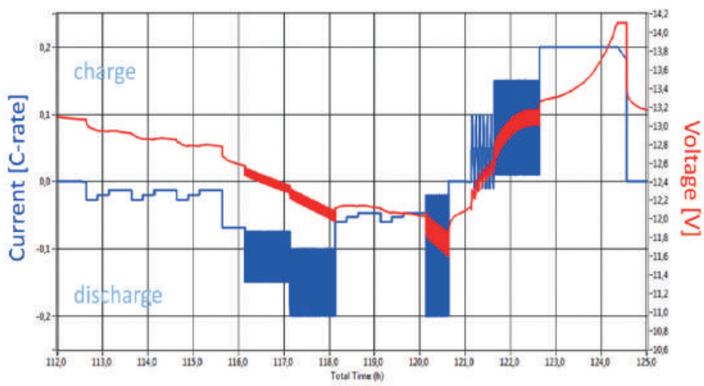


Figure 5 (above): Battery cell resistances of li-ion batteries of different sizes and chemistries

Figure 6 (below): Battery test cycle for solar batteries in grid connected dwellings



Batteries for self-consumption application are often not fully recharged due to the lack of sunny hours outside summer. This is represented by discharging the battery with 20% depth of discharge (DOD). Every two weeks the battery is fully recharged. For lead-acid batteries this can be a severe condition since it can lead to sulfation, which decreases the capacity. The dynamic cycle covers 50% DOD. When a 70% (20+50) DOD is not possible, the whole cycle is scaled according to the allowable DOD. See Figure 6 for a graphical representation. Since various batteries (VRLA, li-ion) have already been tested, you can compare your battery to them.

Open intelligent PV test bench offering algorithm and hardware development within a smart building

This test bench is an open platform enabling local consumption maximisation and other ancillary services. The PV battery system consists of 2 DC/DC converters, one interfacing the battery and one interfacing the PV installation, and one inverter used for grid connection. All three power electronic modules share a common DC bus. Different operating states of the system are identified: the state of the system depends on the state-of-charge of the battery, the power output of the PV installation, and the required grid current. A unique, new control method is applied using DC-bus signalling to switch between the different operating states of the system. The use of DC-bus signalling ensures an inherent reliable system as no internal communication is required between the different modules. Also, the external communication is reduced to one inverter setpoint, while the capacity limits of the storage system involved are always respected. The platform allows the development of:

- algorithms to interact with the (smart) grid
- algorithms to assess the battery's state of charge and lifetime optimisation
- battery testing in a typical household environment

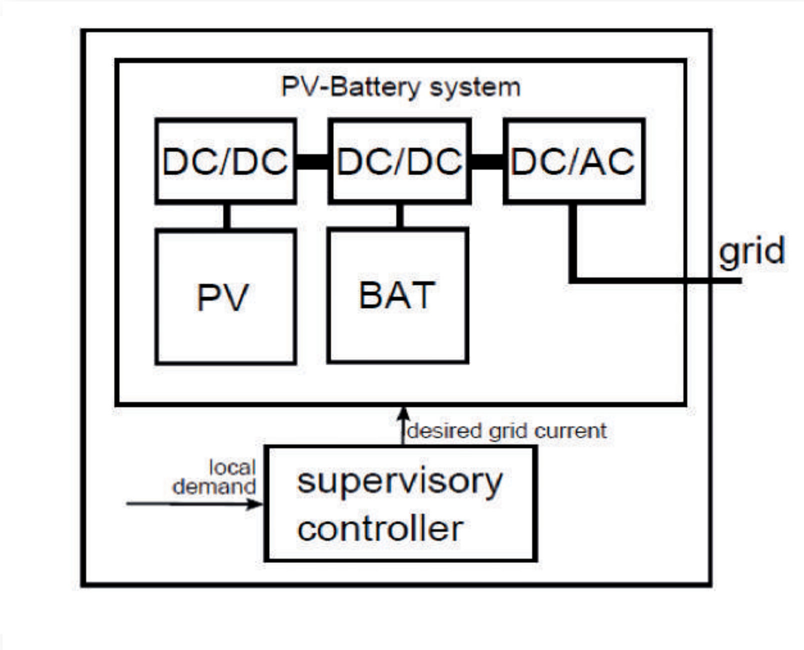
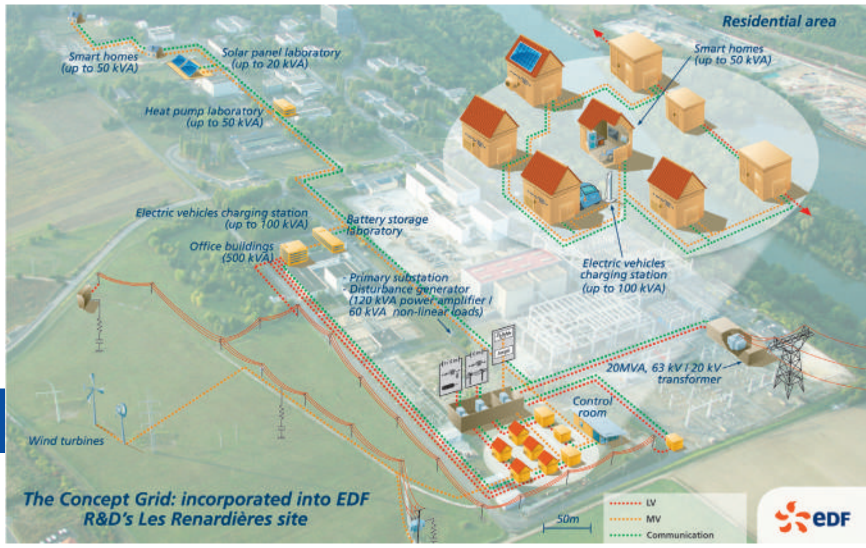


Figure 7 (above and left): The open Intelligent PV test bench and a schematic overview of it in the VITO unit Energy Technology

Transdisciplinarity of the Concept Grid in the smart grid revolution

At the forefront of all major energy challenges, EDF R&D has created Concept Grid on its "Les Renardières" site in the south of Paris. It is a unique experimental platform to anticipate and support the evolution of electrical systems.



The Concept Grid: incorporated into EDF R&D's Les Renardières site

This set of facilities operates under medium and low voltage and allows a wide range of experiments, making Concept Grid a first-rate tool for preparing tomorrow's networks. Its unique design places it mid-way between laboratory tests and experiments in the field. Concept Grid makes it possible to conduct, in complete safety, complex testing campaigns that would be impossible to perform on a real network.

Concept Grid was inaugurated on 13 September, 2013. Within its first year of operation, it has already shown its ability to address complex problematic issues and help manufacturers to boost their developments. These three short examples of performed experiments show the transdisciplinarity of Concept Grid and its place in the smart grid revolution.

Frequency regulation: test of a 1 MW storage system

To maintain frequency, the operator uses the energy available through the primary reserve by blocking part of their production capacity. Battery storage systems provide producers and grid operators with more flexibility over the immediately available energy supply.

For this experiment, Concept Grid has installed and tested a 1 MW battery. A four-quadrant amplifier has enabled frequency variations on the grid, after which the battery absorbed or injected energy in order to keep 50 Hz on the grid. For manufacturers, this experiment proves that nothing can go wrong once in the field.

By relying on both long-term partnerships and more occasional cooperation, Concept Grid shows through these examples that it has been designed to be the privileged testing environment for different stakeholders: universities, laboratories, network managers, equipment suppliers and energy retailers.

Fault detectors: 25 years of feedback in only one week

The VENTEEA demonstrator project aims to study and test new solutions and products designed to adapt the medium and high voltage grid to wind production in medium and high voltage. For this purpose, Concept Grid has been asked to test fault detectors on MV overhead lines.

50 short-circuits were tested during one week. Reference measurement data brought by EDF are compared to the prototype's measurements, which in the field will face a failure rate of 2 faults per year. For manufacturers, Concept Grid boosts development and ensures the integration of wind production.

Load shedding: demand side management

In order to help the integration of intermittent energy sources, load shedding has been tested on Concept Grid relying on smart meters architecture. The purpose is to improve the management of the overall electricity demand of a region or a country through the reduction of consumption peaks.

On Concept Grid, five houses permit testing this scenario, alternately switching heat pumps in each home for a short moment. Cyclic load curtailment makes use of advanced capabilities of smart meters and improves the management of electricity demand.

Communications, Process Control and Energy Efficiency in the Industry Laboratory of the Technical University of Sofia

The laboratory for Communications, Process Control and Energy Efficiency in the Industry Laboratory (CPCEEIL) (Figure 1) is part of the Faculty of Automatics of the Technical University of Sofia. The laboratory consists of the thermal heating system, chemical reactor, vacuum furnace, pressure box for the paper industry and other physical models of real industrial equipment. The control systems are PLC-based (programmable logic controllers). All of the facilities are equipped with individual electrical power analyzers. The control systems are networked with PROFIBUS, PROFINET and MODBUS TCP communication interface and are included in the central SCADA system (Figure 2).

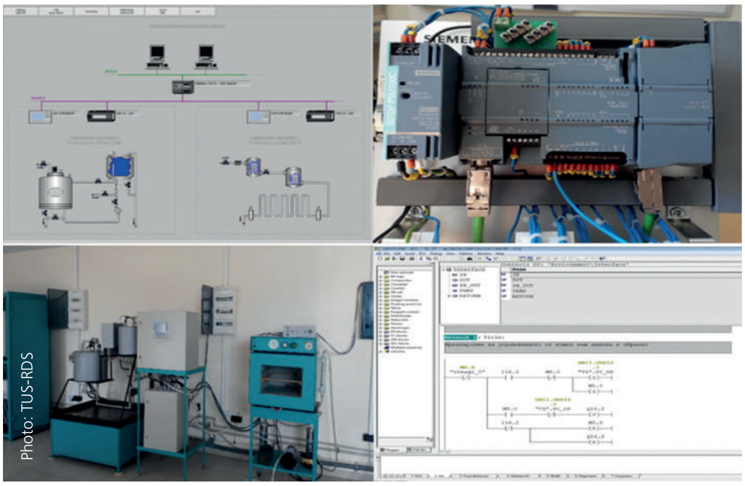
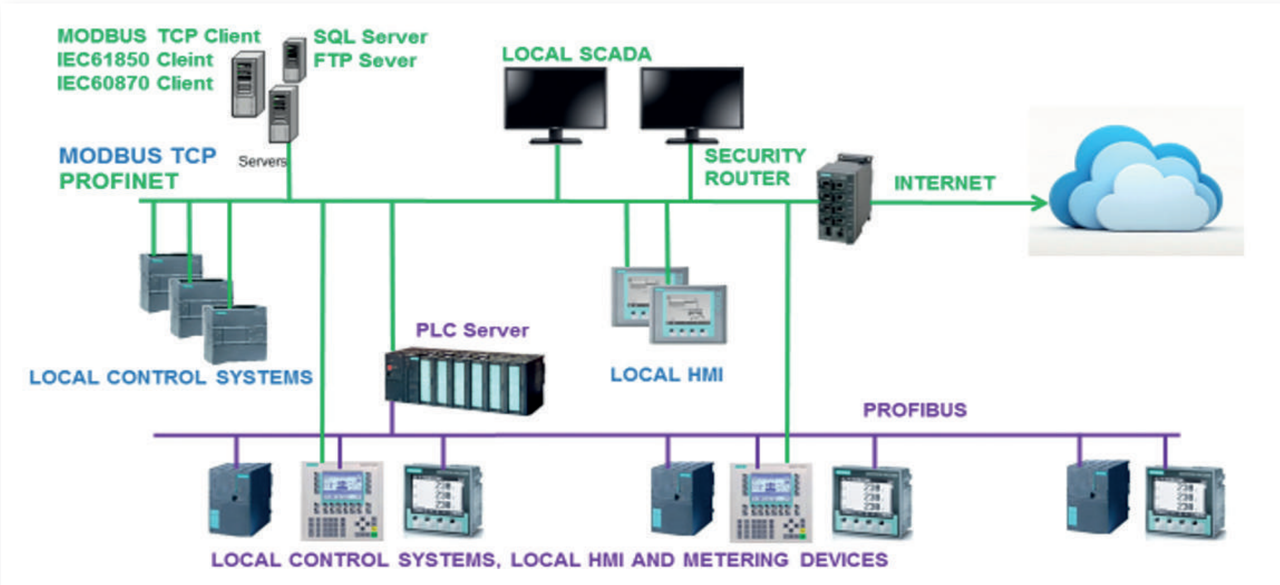


Figure 1 (right): Facilities, SCADA and control systems overview

Figure 2 (below): Network and process control systems structure in the Industry Laboratory of the Technical University of Sofia



The laboratory is equipped with industrial HMI panels for process control. Algorithms for energy saving process controls, demand side energy forecasting and electrical loads control and optimisation are developed and tested in the laboratory. The algorithms are implemented in PLCs. OPC, SQL and FTP servers are installed for data acquisition and secure data transfer via the Internet. Support of the protocols IEC61850 and IEC60870 is included. Data mapping between SIMATIC NET process data and IEC61850 is also carried out in the laboratory (Figure 5).

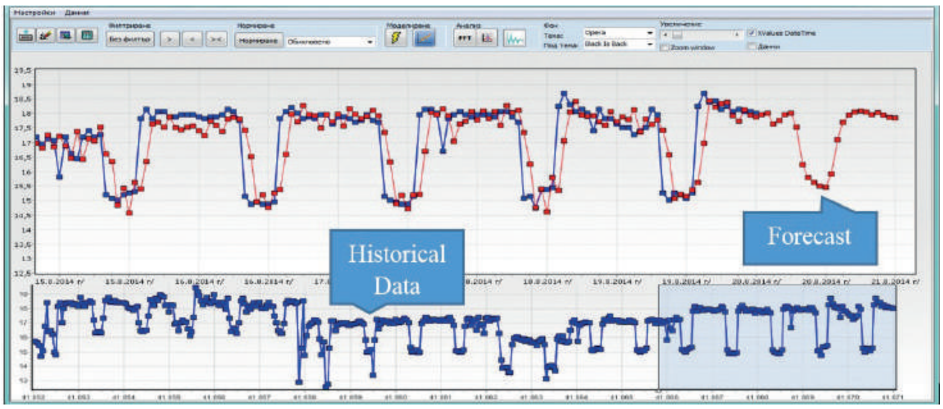


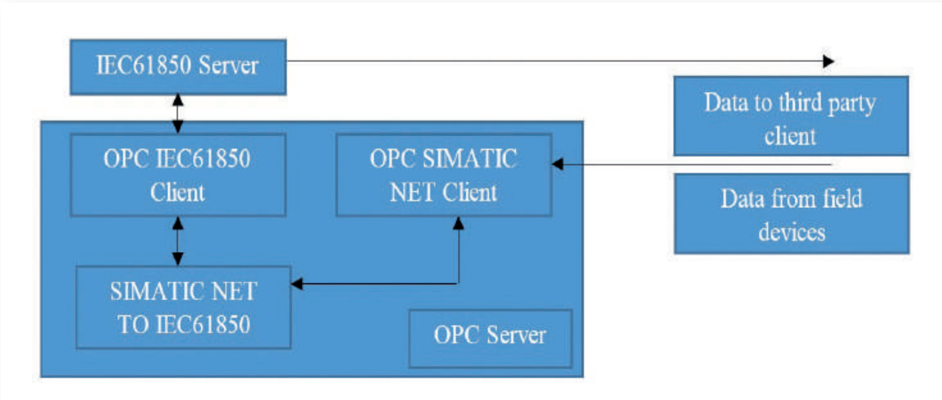
Figure 3: Demand side energy forecasting

Figure 4 (left): Online scheduling of electrical loads

Figure 5 (below): Data mapping for IEC61850 data transmission

The laboratory is involved in the following activities:

- industrial process control systems
- energy effective process control
- process control optimisation
- industry-related communication issues including network security
- SCADA systems development
- OPC and SCADA systems for remote process control and measurement
- energy loads control and scheduling (Figure 4)
- data acquisition and networking in the industry in general and the energy sector in particular
- energy production and consumption forecasting (Figure 3)



The research is carried out by Assoc. Prof. Dr. Metody Georgiev (georgievmg@tu-sofia.bg).

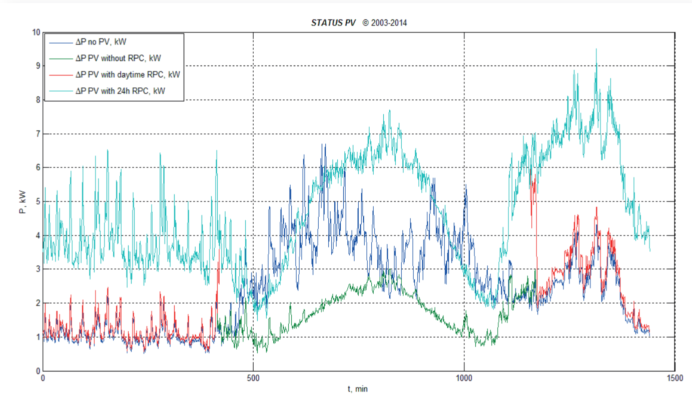
At the 16th International Power Electronics and Motion Control Conference and Exposition (PEMC 2014) a research team from the Research & Development Sector of the Technical University of Sofia (TUS-RDS) and from the Department of Electrical Engineering of the Nova University of Lisboa (UNINOVA) (Stanimir Valtchev, Rui Medeiros, Anastassia Krusteva, George Gigov, and Plamen Avramov) won the best paper award for their paper "A Wireless Energy Transceiver Based on Induction Heating Equipment". The cooperation took place within the frame of the DERri project.

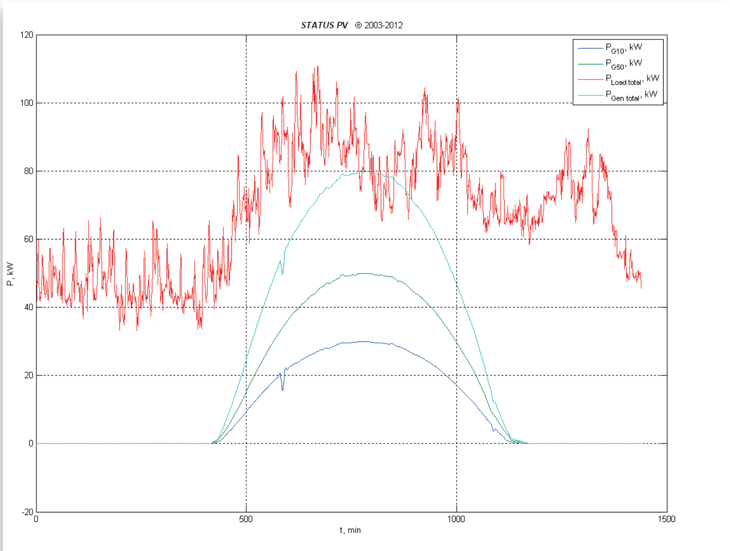
TECHNICAL UNIVERSITY SOFIA

Electrical Power System Stability Laboratory of the Technical University of Sofia

EPSSL of the Technical University of Sofia

The Electrical Power System Stability Laboratory focuses on modelling, analysis and management of multiple-node smart grids and Electrical Power Systems with Distributed Energy Resources (DER) and Electric Vehicles (EV). Using a specialised software and hardware research platform, the laboratory performs power system stability, reliability, security and interoperability tests of multidimensional distribution networks and microgrids with EV and DER.
The computational platforms allow static and time domain estimation of the impact of EV charging, DER control, smart load, and storage control strategies on the network. The infrastructure also allows power system stability studies in case of cyber security violations.

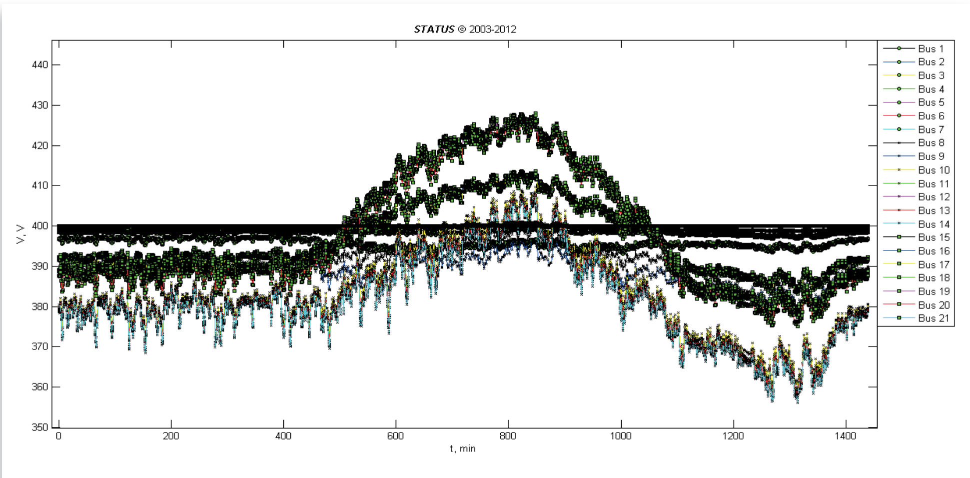




Figures 1, 2, and 3 present a test case of the distribution network with DER load and PV generation power, voltage profiles and power losses under different control strategies over a 24-hour simulation period.

Figure 1 (above left): Power losses in the test case
Figure2 (above right): Generation and load
Figure 3 (below): Voltage without reactive power control

The work is carried out by the research team of Assoc. Prof. Dr. Rad Stanev (rstanev@tu-sofia.bg).

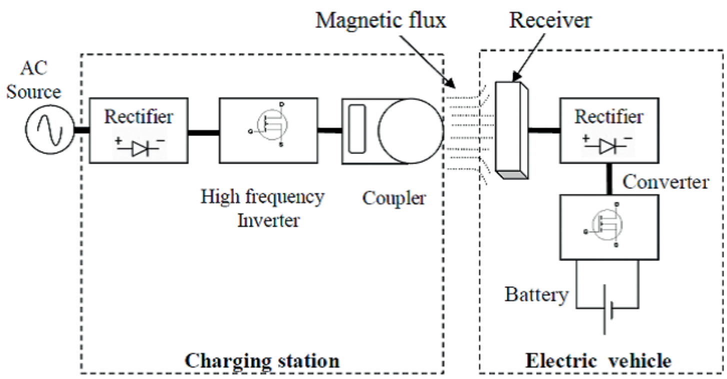


Electric facilities in the Laboratory of Renewable Energy Sources of the Technical University of Sofia

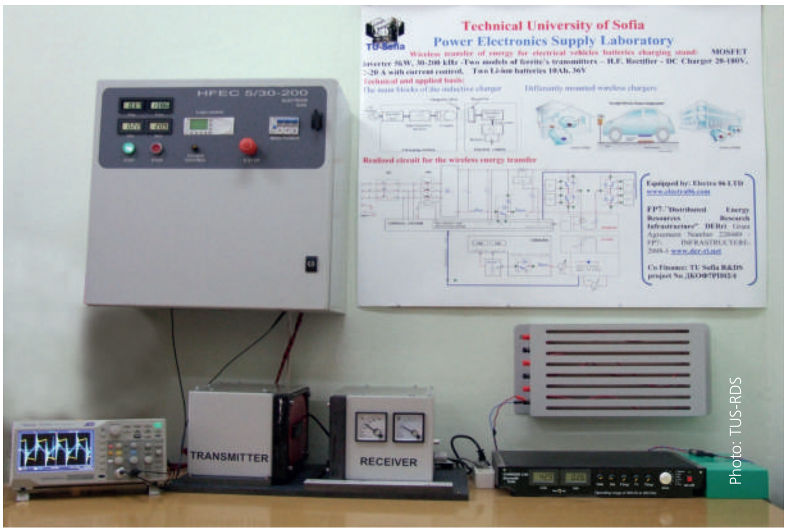
The Laboratory of Renewable Energy Sources conducts research and training activities in the field of electric energy conversion and application using RES. The research team carries out experimental and theoretical research on PV systems, wind energy conversion systems, power electronic converters, hybrid systems with RES, and the integration of PV generators using different technologies in buildings. In 2013 the laboratory obtained an experimental PV systems facility in the framework of the University Research Complex (DUNK 01/3).

Facilities of Prof. Lazarov's research team at the Laboratory of Renewable Energy Sources

Wireless Charging of EVs in the Power Electronics Supply Laboratory



Above: Main blocks of the inductive charger
Below: The realised stand during the charging regime of operation



The new wireless charging stand for li-ion batteries of electric vehicles at the Power Electronics Supply Laboratory of the Technical University of Sofia is equipped for research and practical work by students:

- Rectifier-HF inverter 5kW, 30-200 kHz
- Ferrite's Transmitter-Receiver with 50-150 mm distance
- HF Rectifier
- DC charger 20-180V, 2-20 A with current control
- Load resistors 30-150 Ω
- Two li-ion batteries 10Ah, 36V

The research team carried out an experimental and theoretical study of the efficiency of inductive wireless charge depending on distance, loads, frequency and mode of operation.
Proposed by:
Assoc. Prof. Dr. Anastassia Krusteva (krusteva@tu-sofia.bg)
Assist Prof. M.Sc. George Gigov (georgegi@abv.bg)

Smart Grids Testing and Certification in TECNALIA

www.tecnalia.com

Contact:
aitor.kortajarena@tecnalia.com

Photo: TECNALIA

Facilitating the development of smart grids, TECNALIA is active in several standardisation bodies. In the Smart Grid Co-ordination Group based on the Mandate 490 of the European Commission, TECNALIA is involved in four Working Groups to develop a framework for performing continuous standards enhancement and smart grids development while maintaining transverse consistency and promoting continuous innovation.

As a certification laboratory specialising in smart meters, TECNALIA is also involved in the Technical Working Groups of multiple associations. In the PRIME Alliance, TECNALIA has worked on the PRIME v1.4 specifications; in the Meters & More Association, TECNALIA has worked on including the DLMS protocol in the Meters & More stack.

InGRID - new technologically advanced experimental infrastructure

The purpose of InGRID is to manage electric power in a more efficient and smart way throughout the entire process - generation, transmission and distribution, until it reaches the end user.

In 2014 TECNALIA presented its new smart grids laboratory InGRID, comprising technologically advanced research and testing facilities. The laboratory operates with great experimental capacity in high-voltage and high-power to serve the needs of electrical equipment manufacturers and utilities in the specification, development, validation and commercialisation of innovative products on the smart grids market.

InGRID platforms and laboratories interface traditional electrical engineering capabilities with advanced power electronics and ICTs technologies to cope with the needs of smart product development in the era of future smart grids.

InGRID allows electrical equipment manufacturers to validate their new developments - from the prototype to the final product. For utilities InGRID offers evaluating the equipment performance and functionality for their massive deployment into the grid ensuring their safety and reliability.

TECNALIA's new experimental infrastructure for Smart Grids is based on a series of laboratories for cutting-edge research on electrical system technologies. They will be used to manage electric power in a more efficient and smart way throughout the entire process - generation, transmission and distribution, until it reaches the end user.


Photo: TECNALIA

Power Laboratory: Laboratory connected to the transmission network at 220 kV; the greatest independent Power Laboratory in Spain and Portugal.

High Voltage Laboratory: Two test bays for executing dielectric tests for high voltage products up to 362 kV.

Low Voltage and Environmental Laboratory: Complementary low voltage, climatic and mechanical tests to complete full type testing.

Power Electronics Laboratory: Supports the integration and increased efficiency of the main energy applications and systems (PV inverters, wind converters, electrical energy storage, electric vehicle, active filters for Smart Grids).

Microgrid and Distributed Generation: Design and development of advanced architectures and energy management systems for the integration of small scale generation units into the grid.

Electromagnetic Compatability Laboratory: Immunity and emission testing for electric-electronic low voltage products and for communications; measurements of radio acceptance for telecommunications equipment.

Smart Metering Laboratory: International reference laboratory for the certification of smart meters and data concentrators.

Smart Grids Conmmunications: Functional and interoperability assessment of products for smart grids; development and evaluation of solutions for transformation centre automation and monitoring.

On-site Testing Laboratory: Diagnosis and predictive maintenance of large electrical equipment - generators & power transformers installed in power and industrial plants.

Resonant System for High Voltage Cables: Variable frequency resonant system WRV 260/80 that allows the testing of on-site cables up to 400 kV rated voltage; experts in on-site measurements of partial discharges.

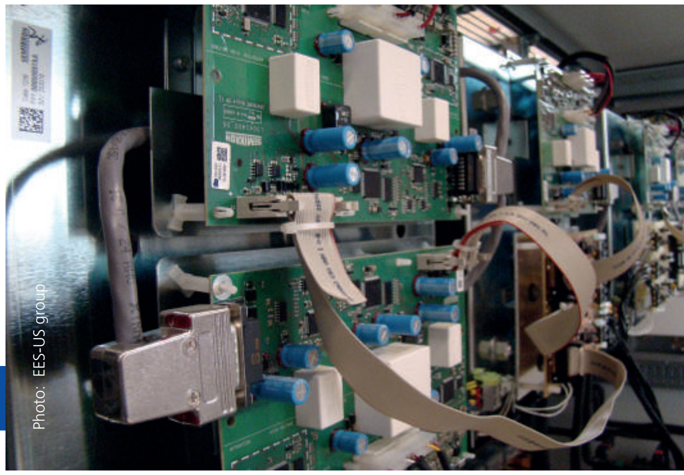
Energy Storage: Improvement of both energy storage costs and performance at all levels of the value chain.

Electric Systems for Renewable Energy Generation: Energy generation based on renewable energy on a small scale.

Electrical Vehicle Network Connection: Assessment of various new technologies and products related to EV charging as part of a complex energy, communications and information system.

Power Engineering and Research in the EES-US Group

The Electrical Energy Systems group of the University of Seville (EES-US) was created 30 years ago and conducts multiple research activities in power engineering and maintains strong connections to the national industry and utilities.

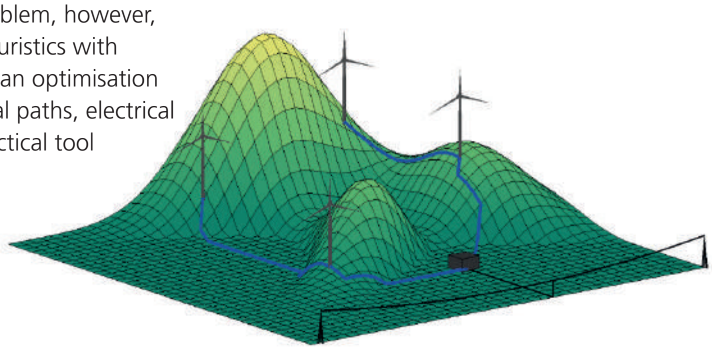


Above: Back-to-back voltage source converter (500 kVA, 400 V)

Below: Optimal planning of wind farms

Optimal planning of wind farms

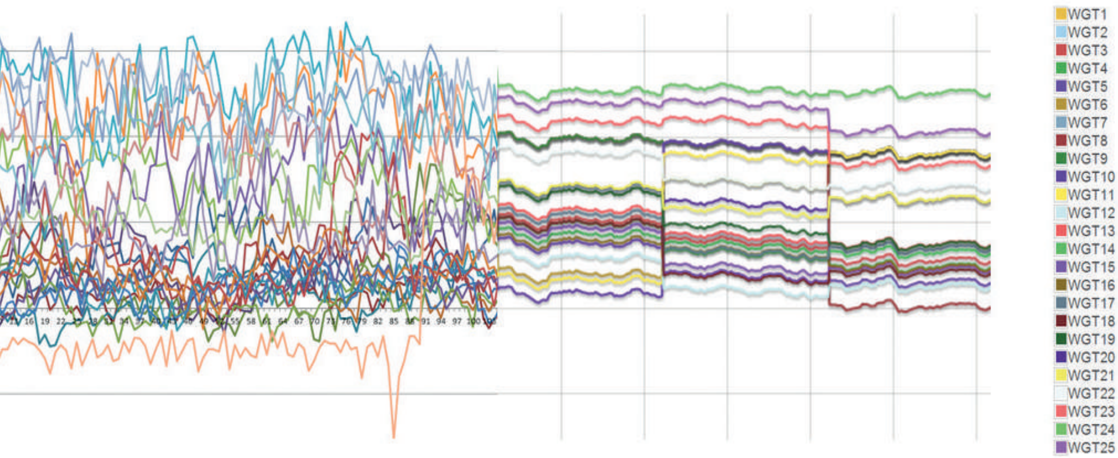
The planning strategies of wind farms are based on the maximisation of the Net Present Value considering the wind farm life cycle. The complexity of this problem, however, usually requires the application of methodologies combining metaheuristics with conventional optimisation methods. The EES-US group has designed an optimisation process simultaneously considering the wind turbine location, internal paths, electrical installation, substation location and evacuation lines, providing a practical tool that solves in a single step all the design stages of a wind farm.



Optimal operation of large-scale wind and PV farms

Grid codes are technical specifications defining minimum technical requirements for Renewable Power Plants (RPPs) to be connected to transmission/distribution networks. To comply with these technical requirements, usually a centralised park level control system called Power Plant Controller (PPC) is required in large-scale RPPs. Voltage and reactive power control capabilities are usual in PPCs.

Most of them, however, implement very simple procedures to fulfill these volt/VAR requirements, taking into account neither all of the available control resources nor their optimal settings. The EES-US has developed an advanced solution that maximises the active power production by using adequate reactive power resources. The tool is tailored to each renewable farm, being flexible enough to take into account the needs in each case.



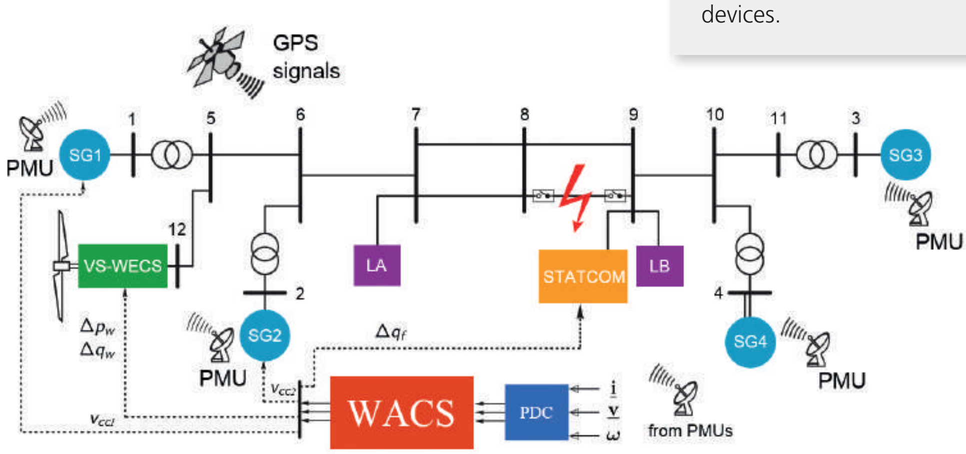
Reactive power of wind turbines before and after optimal control

Wave energy

This is the energy contained in the ocean waves that can be converted using different technologies. Most of them are in their initial prototyping stage. One of the most promising technologies is based on a point absorber converter that uses a direct-drive linear generator connected to the grid by a power electronic based converter. Due to the strong interaction between the wave and the heave-buoy system in all these devices, it is mandatory to implement an adequate control strategy in the coupling converter. The ESS-US group has developed new control strategies with the aim of maximising the energy injected into the system.

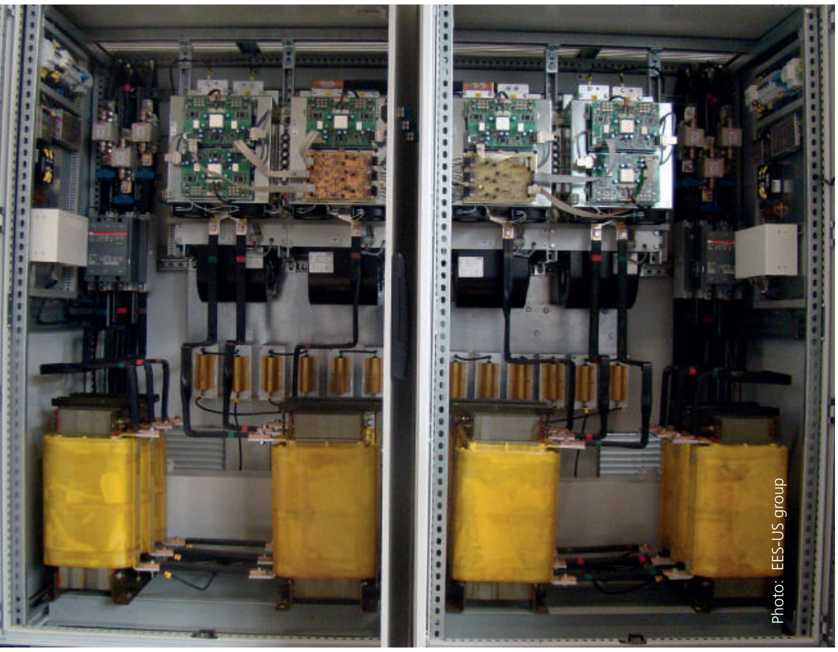
Wide-area control using PMUs

Power systems are undergoing several radical and extensive changes, such as the clear trend for generation systems to increasingly incorporate the energy coming from renewable sources, displacing as a consequence conventional fossil-fuel generators. In addition, the need to accommodate higher levels of load and remote wind, solar and wave generation is pushing transmission lines to their stability limits, causing inter-area modes to become more lightly damped. Wide-area coordinating (WAC) controllers using global remote signals have been suggested since the introduction of the phasor measurement unit (PMU) technology. In this context, the ESS-US group looks for solutions to enhance stability margins and to control oscillatory modes by adding supplementary damping devices.



Wide-area control using PMUs

Integration of power electronic devices in distribution networks for maximising the penetration of distributed generation

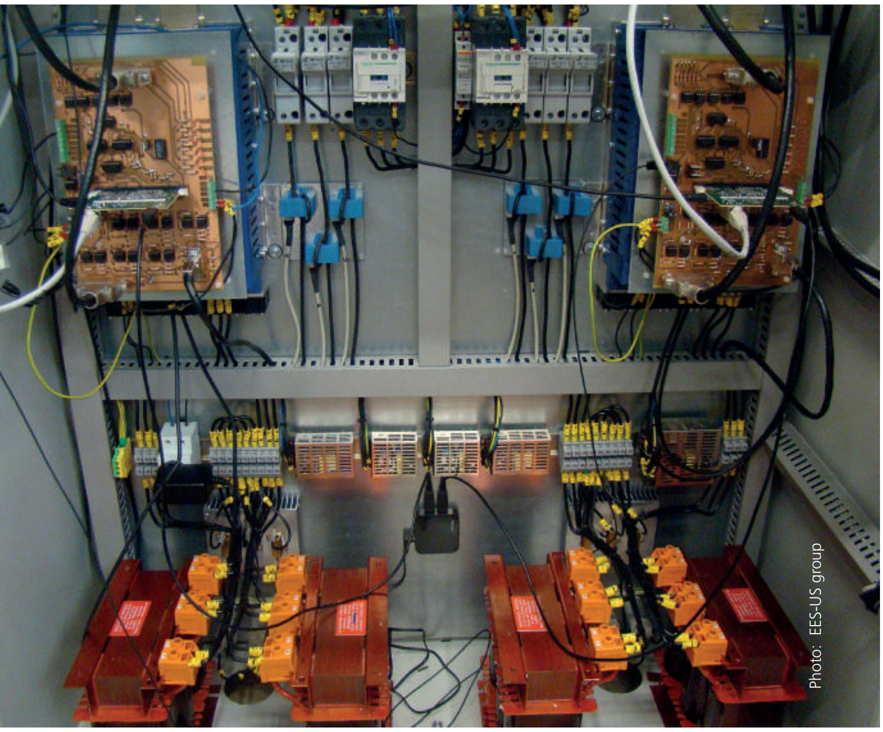


Back-to-back voltage source converter (500 kVA, 400 V)

The continuous growth of distributed generation at the medium voltage level of distribution systems is posing new challenges to utility engineers. The traditional operation and planning paradigm must be reconsidered in order to allow the maximisation of the renewable energy sources at these levels of the power system. In this context, power electronic devices offer multiple possibilities, the control of flows and/or voltage magnitudes being of most interest to further extend the capacity of existing grids, postponing or even avoiding the addition of new network assets. Although the application of this technology has been thoroughly assessed at the transmission level, its extension to distribution systems has not been fully explored. The ESS-US group has proposed to use power electronic based converters to link radial feeders of medium voltage distribution systems to increase the penetration of distributed generators.

Contribution of distributed generation to ancillary services

The problems arising from massive penetration of distributed generators are well-known: voltage regulation problems, reverse power flows, reduction of power quality, malfunction of protective devices, etc. In spite of this, one cannot forget that this number of distributed resources along the distribution networks can provide a number of benefits to the utility in case of an adequate operation, turning the problems into opportunities. The majority of distributed resources are connected using power-electronics-based converters capable of controlling the reactive power injection. Therefore, it should be possible to regulate the voltage at the point of common coupling considering the local (maintain the voltage within the regulatory limits) or the global (minimising the power losses of the distribution system) objective and even to minimise the unbalance using the adequate injection of active and/or reactive power in each phase. The ESS-US group has developed a scaled-down distribution system to test how the distributed generation can provide all these ancillary services to the utility. The impact of distributed generation, performance of new local controllers, new centralised control algorithms, etc. - all this can be tested in this scaled-down system as a prior step to the actual integration within a utility.



Above: Scaled-down distribution system based on the CIGRE TF C06.04.02 (part of the network branches)

Left: Scaled-down distribution system based on the CIGRE TF C06.04.02 (the VSCs emulating loads or generators)

UNIVERSIDAD DE SEVILLA

SnT: Netpower DemoLab

In 2014, SnT has extended its available hardware equipment with three fully programmable voltage source inverters at a four quadrant mode with programming access down to the FPGA level, each with a 10kW DC source. For high power motor tests, a liquid cooling unit has been installed, and it is currently being used in a thermo-electricity project.

SnT
securityandtrust.lu

In collaboration with the Luxembourgian utility CREOS

SCADA Security

Based on the hardware, a virtual topology of the CREOS network is implemented in Emulab. The project partner CREOS contributed three routers (Alcatel Lucent 7705 SAR-8), three breakout panels, rack, network connectivity and power supply. A Dell control server acts as an interface between the network and the CREOS routers. External connections use a dedicated isolated subdomain with a IPv4 address visible from the outside and different from connection to the IP/MPLS routers. Virtual Leased Line (VLL) or pseudo-wire provides Ethernet-based point-to-point communication over IP/MPLS networks and transports Ethernet traffic over an MPLS tunnel across an IP/MPLS backbone using CPIPEs (emulating a point-to-point time division multiplexing (TDM) circuit). It is planned to connect with power generation hardware in order to send distribution grid model signals through SCADA devices simulating short circuit current contribution information transfer.

Compound Data/Power-Network Reliability

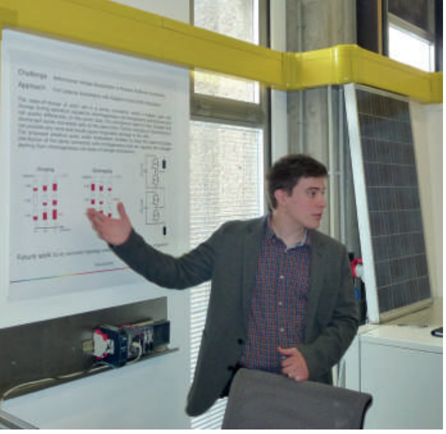
Using the available programmable voltage source inverters, pseudo-random binary series (PRBS) are modulated on the power signal in order to estimate power line impedances and obtain broad spectrum identification during online operation. Objectives are the estimation of grid impedance, detection of harmonic resonances and fault detection in cases of adaptive protection mechanisms use.

Laboratory tour and demonstration at the inauguration of Netpower DemoLab

Photo: Daniela Neuschäfer, DERlab

Thermoelectrics in preparation with the University of Duisburg-Essen

The system integration of thermoelectric generators in many new industrial applications is still confronted with obstacles based on the basic understanding of its operation and efficiency. Especially the impact of dynamics from both the electric load (e.g., due to the inverter usage) and the incoming heat flow should not be neglected if they occur during the application. In order to validate new modelling approaches, a test stand is constructed in Netpower DemoLab to measure the conversion efficiency of thermoelectric modules and material probes in the transient regime with a controllable electric load facilitating a high current/voltage change rate.



State-of-charge equalisation in li-ion stacks in preparation with RWTH Aachen University

Large lithium-ion battery packs are progressively used in electric vehicles and as grid connected storages. The battery packs are equipped with balancing circuits which keep the cells state of charge equalised. Without the state-of-charge equalisation, the cell storing the lowest energy limits the usable energy of all the other cells within the string. This project investigates the additional degradation of the cells caused by various balancing circuits. Simulations and real laboratory tests are under preparation to assess the operation methods.

Micro-kinetic turbine in collaboration with RWTH Aachen University

In the Luxembourgish Fonds National de la Recherche (FNR) funded project "Integration of distributed controllable renewable generators in the Luxembourgish electricity system including innovative micro-hydro-kinetic turbines", a novel hydro-kinetic oscillating wind turbine is developed with variable immersion depths. A lab setup has been built prior to testing the turbine in a river in Luxembourg. The turbine is controlled by two standard inverters, which control two machines, harvesting energy from the motion of the foils. The controlled motion will be self-adapting to variable flow conditions via observers. The test setup has been successfully completed in Netpower DemoLab, and the construction for the river test is under way.

Top: Laboratory tour and demonstration at the inauguration of Netpower DemoLab
Below: DERlab Workshop "Power System Testing", April 2014, Luxembourg (LU)
Bottom: DERlab General Assembly

Power System Testing and Power Security from DER in DERlab

On 3-4 April, 2014, DERlab held its General Assembly hosted by SnT at its premises in Luxembourg, which was collocated with the inauguration of SnT's Netpower DemoLab, the new facility conducting research, testing and development in security and reliability of distributed generation in the power grid. Particular focus points of Netpower Demolab concentrate on component reliability and security, distributed systems reliability and security, and communication security on the control, supervisory control and integration levels.
The technical discussions at the General Assembly were enriched by the workshops held at the event. The DERlab workshop on "Power System Testing" addressed this key research, testing and development topic for DERlab in the context of ISGAN SIRFN activities. DERlab members presented their current laboratory practices in power system testing and addressed the following discussion points:

- Definition of "system" in the context of power system testing
- Insufficiency of components testing and related grid problems

The following joint SnT/DERlab workshop on "Power Security from Distributed Energy Resources" addressed major trends in distributed generation and grid integration in the next decade and related challenges. The discussion was aligned along:

- Overall Reliability and Supply Security
- Risk Assessment and Reliability Testing
- Short Circuit Protection
- Cyber-Infection Protection
- Overload Protection
- Multi-Unit Stability and Robustness

Validation of Control Services in SYSLAB at the DTU Electrical Engineering

A vision of SYSLAB as a test bed for system testing supports the development, deployment and validation of distributed control algorithms including the use of co-simulation techniques. The laboratory infrastructure and test platforms for aggregator algorithms are under continuous development.

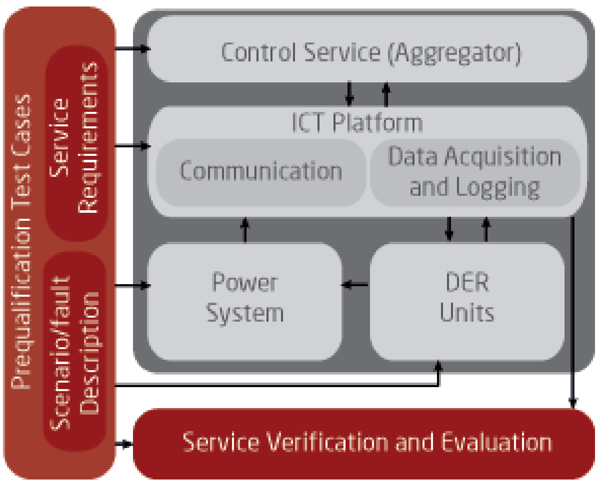
Daniel Esteban Morales Bondy, Anders Thavlov, Kai Heussen, Henrik W. Bindner

When moving from the traditional sources of ancillary services to Demand Side Management (DSM) schemes, new actors and roles emerge in the power system. It is expected that the DSM is provided by a new entity, an aggregator, therefore, new validation methods are needed to ensure the performance of the aggregator. Traditionally, validation is done by ensuring that the generators providing the ancillary service comply with certain requirements (e.g., specific measurement and logging equipment) and pass a pre-qualification test. The pre-qualification test varies depending on which ancillary service is to be delivered but a common element is that the test metrics are designed for single large generation units. Therefore, traditional pre-qualification tests and requirements are not suited to validate distributed systems where the aggregated behavior of many small units provides a service to the grid. For example, it would not be economically feasible to have certified high-precision measurement instrumentation at each unit in an aggregator portfolio. Alternatively, the prequalification should remain valid for smaller changes in the aggregator portfolio. Part of the research performed at the Center for Electric Power and Energy of the Technical University of Denmark (CEE DTU) is to define frameworks and identify new methods for validating aggregators providing Control Services using distributed energy systems.

The framework for aggregator validation seen in the picture on the right covers both regulatory and technical aspects:
• Regulatory Aspects (marked in red) cover the definition of the services to be provided, the capabilities that an aggregator should offer, and how the service delivery should be evaluated and verified.
• Technical Aspects (marked in grey) present functions designed to be modular so that the aggregator can be tested on either a pure hardware laboratory setup, pure simulation setup (e.g., using co-simulation tools) or by hardware-in-the-loop simulation.

The research team has developed and published a method for the performance assessment of aggregators [1] supporting the service verification and the evaluation aspects. This method has been implemented using the SYSLAB hardware and the software platform [2] and is to be tested on existing demand response algorithms in the laboratory. Further work is expected on pre-qualification test cases.

The Energy Systems Operation and Management Group of DTU CEE conducts research on development and testing of smart grid solutions addressing both technical and regulatory aspects. Experience in technical research is reflected in the advanced capabililties of SYSLAB, a laboratory continuously progressing in anticipation of smart grid and smart energy systems developments [2,3,4]. Research on regulatory aspects has recently received more attention due to its crucial role in the deployment of smart grid control technologies.



Validation framework for control services

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SYSLAB in the Smart Grid Infrastructure Demonstration

Daniel Esteban Morales Bondy, Anders Thavlov, Kai Heussen, Henrik W. Bindner

iPower Architecture Demonstration

iPower is a large demonstration project where universities and industrial partners consolidate innovation and research activities for the purpose of developing intelligent control of decentralised power consumption [1]. As the number of commercial entities involved in the operation of the power system increases, it is required that the interaction between parties is increasingly formalised and automated. For this purpose, a Flexibility Clearing House (FLECH) has been developed in order to facilitate the business related interactions between system operators and aggregators. This article describes the pre-standardisation work that was carried out during the preparation for the dissemination demonstration held in mid-November 2014.

Demand response is expected to be one of the key flexibility assets in the future power system. FLECH is a software platform which matches service needs from system operators with flexible consumption bids from aggregators. Through FLECH, a system operator, such as a distribution system operator (DSO), can open tenders for pre-defined products, which are broadcast to aggregators controlling flexible loads. When bids have been collected by FLECH, the market is cleared after the merit order and aggregators are notified about wining contracts.

The FLECH demonstration presents the interactions between different power system actors, from the market level down to the process level. The objective of the demonstration has been to present the possibilities of trading demand flexibility via a Flexibility Clearing House (FLECH), demonstrating the complete exchange process from announcing a service tender to service delivery, verification and final settlement.

The laboratory for research in distributed control SYSLAB at the DTU Electrical Engineering is a key element in the demonstration. It comprises both a hardware platform and a software platform [3]. The SYSLAB software platform enables fast implementation and test of controllers and system wide functions. The hardware platform consists of several bus bars, to which diverse generation or consumption entities can be connected in any permutation, thus creating a very flexible system setup. SYSLAB entities include: wind turbines, diesel genset, intelligent buildings, photovoltaics, battery storage, and multiple electric vehicles.

Four actors have been involved in the demonstration:

- a DSO, implemented on the SYSLAB platform
- two aggregators, one implemented on the SYSLAB platform and the other implemented by Insero Software
- a commercial partner of the iPower project
- FLECH implemented by IBM as a cloud solution on their Bluemix platform

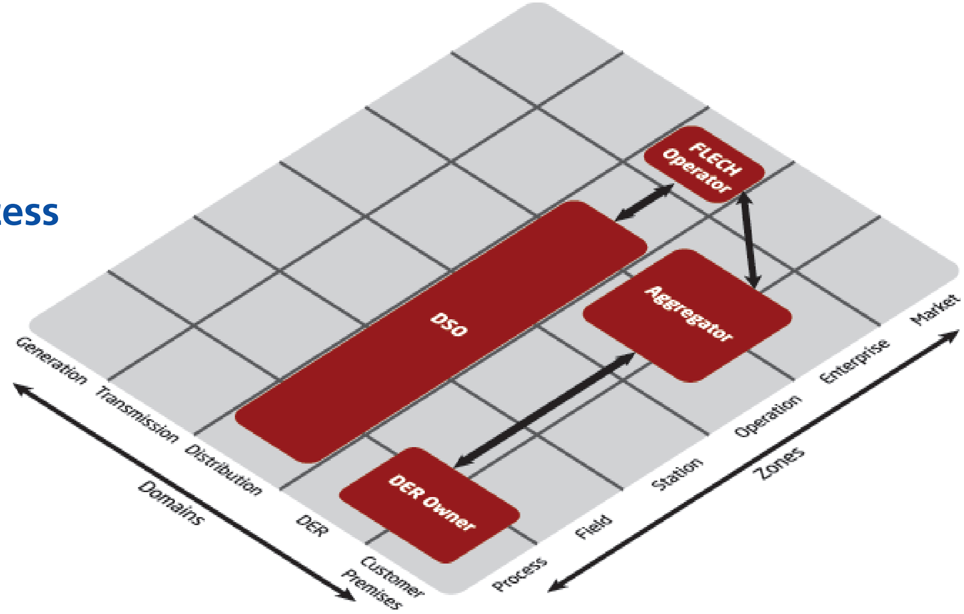
The demonstration brings concepts discussed in [4] and [5] into practical implementation. These concepts comprise the trade of flexibility services through a clearing house, the definition of flexibility products for the DSOs, service delivery from an aggregator controlling a distributed portfolio of small units, and the validation of aggregator offers with respect to a given baseline. Two documents have been created as preparation for the demonstration: "FLECH PowerMax Service Requirement Specification" [6] - presenting the definitions of the market structure, actor roles and information interactions - and "FLECH Fundamental Demonstration Platform Documentation" [7] - partly covering the information interactions and focusing more on the standardisation of communication protocols.

Described below for each zone are the interactions in the demonstration as defined in the SGAM, i.e., from the market down to the process level. Lastly, we list the standardisation needs that have been identified in each zone during the preparation of the demonstration.

Market and enterprise

On the market level, the FLECH prototype was expanded to handle the PowerMax service. In order to support this service, the service had to be defined and analysed in depth [6]. In order for it to interface with FLECH, the research team created two programs: one program in SYSLAB, which opens market tenders and bids flexibility services, thus acting both as a DSO and an aggregator, and another program with Insero Software, which also bids flexibility services into open markets. The format and content of the interface between the DSO, FLECH and the aggregator have been defined in [7].

Operation, field and process



The demonstration illustrated on the smart grid plane of the Smart Grid Architecture Model (SGAM) [2]

Part of the portfolio that the aggregator is controlling is an intelligent office building that will serve as a flexible load during the demonstration. On the field level, the aggregator communicates with a building management system (BMS), which controls a range of power consuming processes in the office building, e.g., space heating, water heating and lighting. For the purpose of the demonstration, only the processes from electric space heating will be utilised. From the aggregator the BMS receives a power setpoint through an interface developed specifically for the demonstration. The interface allows a power setpoint to be sent to the aggregatees and, similarly, allows the measurements of power consumption — or generation — to be sent back to the aggregator. Communication between the aggregator and DERs is facilitated by a publicly accessible whiteboard server, to which both actors can communicate.

The whiteboard server, developed at DTU, has proved to be a valuable tool for avoiding communication barriers between the lab and external sites, like firewalls and dynamic IP addresses. The server represents a digital whiteboard to which pairs of keys and values can be written. Although it is not a standardised method of DERs control, the approach of using a whiteboard server has proved effective for prototyping a control architecture. The whiteboard server allows a generic interface to be easily implemented and tested prior to a potential standardisation process. As an alternative to the whiteboard approach, one can make use of existing standards, e.g., IEC 61850.

During the demonstration, the BMS controlled the heaters such that the heating of the building is accelerated or postponed according to the given power setpoint but still considering the indoor temperature limits, which are specified by users of the building. The controlled flexible process is the combined power consumption from ten resistive heaters with a total rated peak power of nearly 10 kW.

Standardisation Work

Progress has been made within the following topics:
• Flexibility Service models for demand response: market roles, business processes, and information models,
• Flexibility Clearinghouse (FLECH) concept
• Live demonstration of DSO Flexibility Services acquisition and operation via FLECH
• Experimental validation of alternative communication strategies

For further details please see [6] and [7].

In order to ensure transparent and effective mechanisms for trading of flexibility services, development is required with respect to:
• Standardised methods for demand response baselines
• Data models for forecasting and other information services
• Methods for verification and settlement of service delivery
• Demonstration of demand response using suitably standardised communication (e.g., OpenADR)
• Integration of demand response services with distribution management systems

Further developments should also account for data management and cyber security requirements.

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CVVOZE

The research infrastructure CVVOZE Power Laboratories (CVVOZEPowerLab) is part of the Centre for Research and Utilization of Renewable Energy (CVVOZE) established in 2010 in the Faculty of Electrical Engineering and Communication at Brno University of Technology.

The Centre aims to become a leading research institute concentrating on research and development capacities for involvement in complex research, development and exploitation of renewable energy sources, including electrochemistry, electromechanics, electrotechnology, power electrical engineering, electrical drives, mobile robots and industrial electronics.

The research infrastructure CVVOZEPowerLab comprises two CVVOZE strategic laboratories – the high current laboratory and the high voltage laboratory. Of the two, the high current laboratory is a unique one due to its high-tech facilities for AC and DC heavy current tests of low and middle voltage equipment.

Above: LV part and the testing bench of the high current laboratory

Below: Generator of the high current laboratory

High current laboratory

This laboratory brings together a unique set of equipment for high current testing. It is possible to conduct standard AC short-circuit tests of low-voltage devices up to 150 kA (250 V - 0.2 s), and short time current withstand tests up to 40 kA (100 V – 3 s). A further unique feature of the laboratory is also its capability to conduct DC tests up to 50 kA (1000 V – 200 ms). The DC source is a large capacitor bank with the highest voltage 12kV for special tests. The complete electrical measurement chain is also accompanied by optical diagnostics together with a high-speed camera with a recording frame rate up to 12 000 frames per second in full HD resolution and a maximum frame rate up to 1 000 000 frames per second with reasonable frames resolution. Also available are high-dynamic pressure sensors for arc diagnostic along with fast and sensitive laser sensors for movement evaluation. This laboratory will enable all experiments to be conducted under real conditions using modern diagnostic methods. Consequently, experimental results of very high quality and originality can be expected.

At the high current laboratory, low and medium voltage equipment is analysed in terms of thermal and dynamic short-circuit performance, opening, breaking, and insulation capacity after short-circuit breaking, and operational behaviour. Short-circuit tests with surge arresters in conformance with standards and including pre-damage can also be performed.

The short-circuit generator can be connected flexibly with a total short-circuit current of up to 150 kA at 250 V for individual tests. Voltage is adjusted to the particular requirements by power transformers.

Parameters of AC tests

AC 50/60 Hz - 200 ms:

- 150 kA / 250 V
- 100 kA / 500 V
- 60 kA / 750 V
- 40 kA / 1000 V

AC 50/60 Hz - 3 s:
- 40 kA / 100 V

AC 16 2/3 Hz - 200 ms:
- 50 kA / 1000 V

Parameters of DC tests

50 kA / 1000 V - 200 ms ($\leq$ 30 ms)

Diagnostics equipment

- 12 channels of 16-bit depth DAQ 50 kHz certified
- 2 channels of 8-bit depth and 50 MHz bandwidth
- High-speed digital camera up to 1 mil. frames per second
- Measurement of dynamic pressures up to 10 MPa

Tests comply with the corresponding IEC, GOST and UL standards:

- IEC 60947 Low-voltage switchgear and controlgear
- IEC 60269 Low-voltage fuses
- IEC 61439 Controlgear and switchgear
- UL 489 Molded case circuit breakers
- GOST-R (OCT P) 50030 Low-voltage switchgear

Top: CVVOZEPowerLab

Above: High voltage part of the high current laboratory

Impulse generator in the laboratory of high voltage

High voltage laboratory

The main hall of the high voltage laboratory has a floor area of 15 x 10 m and a minimum ceiling height of 9 m. The hall is completely shielded. The attenuation of the laboratory shielding equals 90 dB in the frequency range 30MHz to 1GHz for the electric field and over 60dB in the frequency range 10kHz to 30MHz for the magnetic field.

The high-voltage testing laboratory provides a wide range of possibilities in the field of short- and long-term insulation testing. It has a testing hall and two smaller testing laboratories where it is possible to perform voltage tests, such as lightning impulse voltage, alternating voltage, direct voltage, and switching impulse voltage, as well as combined voltage tests.

In parallel with the voltage tests, other examinations can be performed, among them are measurements of conventional and UHF partial discharge (PD). Also the water treatment plant is being prepared for future artificial rain tests. If required, monitoring camera systems and microscopes can be used.

The test hall and one small test room are shielded, which enables sensitive PD measurements with a very low noise level of less than 1 pC. The high voltage laboratory also allows tests of the breaking capacity of GIS breakers. Also available are surge current test circuits for surge arrester tests.

Maximum test voltages of technology

- Alternating voltage (50 Hz) 300 kV, 1A
- Lightning impulse voltage (1.2/50 μs) 935 kV, 100 kJ
- Switching impulse voltage (250/2500 μs) 750 kV, 100 kJ
- Direct voltage 140 kV, 11 mA
- Maximum lightning impulse current (8/20 μs) 25 kA
- Maximum switching impulse current (30/60 μs) 3 kA

Centre for Research and Utilization of Renewable Energy

Main equipment

- AC high voltage source 300kV
- Impulse generator 1000kV
- Conventional voltage impulse dividers
- Impulse oscilloscopes
- Digital oscilloscope/waveform analyser
- Partial discharge analyser

AC high voltage source in the laboratory of high voltage

Practical Research and Unique Testing Facilities at Lemcko

Lemcko was founded in 1998 as an independent academic research institute focusing on electrical motors, drives and electrical power quality to provide substantial research for its industrial partners. Since then, there has been a continuous growth in manpower, knowledge and expertise in low frequent power quality (<2kHz), general low-voltage electrical installations, energy-efficiency and renewable energy connected to the low-voltage distribution grid. In 2013, Lemcko has become part of Ghent University in order to increase academic collaborations and its international recognition.

Photo: Gerald Van Rafelghem 2014

Over the last two decades, the functionality and the stress on the distribution grid has significantly increased. Lemcko's ambition is not to elaborate on advanced theoretical modelling or forecasting algorithms but instead to facilitate the transition from innovative academic research to real-life integration of these innovations into the low-voltage grid.

The laboratory comprises an extensive amount of practical and theoretical knowledge in combination with a state-of-the-art test facility. Lemcko has a unique test site consisting of 18 real connections of households to an actual distribution feeder of 600m. The combined use of the distribution grid and a 240kVA programmable power source enables testing of innovative consumers and producers as well as measuring equipment in order to tackle future problems related to the practical integration combined.

Lemcko's ambition is to facilitate the transition from innovative academic research to real-life integration of these innovations into the low-voltage grid.

Photo: Gerald Van Rafelghem 2014

In electrotechnical engineering the evaluated frequencies are often limited to the 40th harmonic (or 2kHz). However, recent studies indicate that future problems to distributional grids may include supraharmonics (>2kHz) and electromagnetic compatibility and immunity (>9kHz). The laboratory has expanded its area of application, the test equipment and its expertise to cover these frequency ranges. The availability of a semi-anechoic chamber and the corresponding measuring equipment allows Lemcko to perform IEC and CISPR compliance testing.

It is, however, the lack of power as in voltage dips and short- or long-term blackouts that may affect the end user most noticeably. In 2012, Lemcko initiated a research focusing on small-scale storage and autonomous generation of electrical power. Test facilities include a programmable power electronic converter (Tri-phase platform), 10kWp PV installation with tracking possibilities, net interactive PV converters in combination with battery storage and several autonomous generators. Future investments include a test facility for motor and generator testing of 150kW. This would allow for the possibility to test high power, high current as well as low-speed generators such as the ones used in windmills <100kW.

LEMCKO Energy & Power Quality

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Photo: Lemcko

Photo: Mihai Calin, DERlab

Publications

Conference Papers

Cooperative scientific articles by DERlab e. V. (DERlab member institutes) 2013-2014

Title	Authors	Place of the publication	Affiliation
Comparative assessment of module productivity models	N. Dekker[1], R. Emmerich[2], G. Leotta[3], J. Mertens[4], S.Misara[2], P. Pugliatti[3], A. Di Stefano[3], G. Razongles[4], B. Ya Assoa[4]	EU PVSEC 2014	1. ECN, 2. **Fraunhofer IWES**, 3. **Enel**, 4. **CEA INES**
Thermal and electrical analysis of BIPV systems in the Sophia project	B. Ya Assoa[1], W. Sprenger[2], S. Misara[3], F. Roca[4], L. Mongibello[4], B. Kubicek[5], M. Wagner[5], S. Zamini[5], J. Merten[1], M. Machado[6]	EU PVSEC 2014	1. **CEA INES**, 2. Fraunhofer ISE. 3. **Fraunhofer IWES**, 4. ENEA, 5. **AIT**, 6. **TECNALIA**
Collaborative development of automated advanced interoperability certification test protocols for PV smart grid integration	J. Johnson[1], R. Bründlinger[2], C. Urrego[3], R. Alonso[4]	EU PVSEC 2014	1. **Sandia National Laboratories**, 2. **AIT**, 3. Universidad del Valle, 4. **TECNALIA**
DERri common reference model for distributed energy resources - modelling scheme, reference implementations and validation of results	F. Andren[1], F. Lehfuss[1], P. Jonke[1], T. Strasser[1], E. Rikos[2], P. Kotsampopoulos[3], P. Moutis[3], F. Belloni[4], C. Sandroni[4], C. Tornelli[4], A. Villa[4], A. Krusteva[5], R. Stanev[5]	CIGRE Session 45, Paris, France, 2014	1. **AIT**, 2. **CRES**, 3. **NTUA**, 4. **RSE**, 5. **TUS**
Improving the portability and exchangeability of model data for smart grids focusing on real-time simulations – definition of a common reference model	T. Strasser[1], M. Stifter[1], W. Hribernik[1], E. Lambert[2], P. Kotsampopoulos[3], P. Crolla[4], C. Tornelli[5]	CIGRE Session 45, Paris, France, 2014	1. **AIT**, 2. Électricité de France, 3. **NTUA**, 4. **University of Strathclyde**, 5. **RSE**

Title	Authors	Place of the publication	Affiliation
On the stability of local voltage control in distribution networks with a high penetration of inverter-based generation	F. Andren[1], B. Bletterie[1], S. Kadam[1], P. Kotsampopoulos[2], C. Bucher[3]	IEEE Transactions on Industrial Electronics, vol. PP, issue: 99, 2014	1. **AIT,** 2. **NTUA,** 3. Basler & Hofmann AG
Testing of utility-scale PV inverters - international grid code developments and laboratory needs	W. Heckmann[1], N. Schäfer[1], D. Mincu (Craciun)[1+2]	International Conference on Standards for Smart Grid Ecosystems, Central Power Research Institute (CPRI), Bangalore, India	1. **Fraunhofer IWES**, 2. **DERlab**
Guidelines for testing large-scale RES inverters	G. Arnold[1], R. Bründlinger[2], W. Heckmann[1], N. Schäfer[1], D. Geibel[1]	Deliverable JRA-2.2.3, Distributed Energy Ressources Research Infrastructures (DERri, EU Project no. 228449), January 2014	1. **Fraunhofer IWES**, 2. **AIT**
Introduction of advanced testing procedures including PHIL for DG providing ancillary services	P. Kotsampopoulos[1], N. Hatziargyriou[1], B. Bletterie[2], G. Lauss[2], T. Strasser[2]	39th Conference of the IEEE Industrial Electronics Society (IECON), Vienna, Austria, 2013	1. **NTUA**, 2. **AIT**
Review, analysis and recommendations on recent guidelines for the provision of ancillary services by distributed generation	P. Kotsampopoulos[1], N. Hatziargyriou[1], B. Bletterie[2], G. Lauss[2]	IEEE International Workshop on Intelligent Energy Systems (IWIES), Vienna, Austria, 2013	1. **NTUA**, 2. **AIT**

DERlab Association

DERlab is the network of leading research institutes working together for the grid integration of distributed power generation. The association develops joint requirements and quality criteria for the connection and operation of Distributed Energy Resources (DER) and strongly supports the consistent development of DER technologies. DERlab offers testing and consulting services on grid integration of distributed generation and conducts research on a wide range of related topics, such as:

- Interconnection requirements of DER
- DER and smart grids related R&D
- Grid-connected storage
- Electromagnetic compatibility requirements for DER
- Static converters in grids
- DER testing procedures
- Ancillary services
- Communication
- Photovoltaic modules
- Hardware-in-the-loop
- Network protection
- Electric vehicles

DERlab e. V. Board

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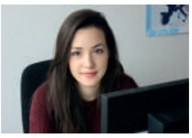

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