

### DERlab

European Distributed Energy Resources Laboratories

### Activity Report 2016/2017

Smart Grids: Advanced Testing Techniques and Procedures Supporting Seamless DER Grid Integration















### Foreword

We are currently observing an acceleration of the changes to the world's interconnected electricity systems, the largest man-made technical constructs on earth, due to the pace of technological and societal developments. Experts unanimously agree that the importance of electricity as 'the fuel of choice' will increase by 60% over the next 35 years, and it will be greener, more affordable and more accessible than ever.

It is important to realise that digitalisation and power electronics are key enablers for the transformational change into a flexible, future-proof, reliable, sustainable and affordable power system, and it is DERIab's challenge to contribute to derisking this transformation through technology development, and laboratory validation and testing.

To reduce the risk of new components and advanced systems of technology before grid installation, rigorous testing is needed. Testing and validation of individual components against industry standards is still essential but will no longer be sufficient, since their response greatly depends on their interaction with the power network and associated protection, control and monitoring systems. Therefore, testing should incorporate this dynamic system interaction. Testing in the field or re-creating a substantial part of the target grid in a laboratory environment is impractical, expensive and risky. It is increasingly being recognised that the combination of real time simulations, together with hardware experimentation supported by cosimulation and hardware and controller in the loop testing, are essential for the validation of any integrated system solution.

DERlab and its members continue to update, develop and utilise advanced testing environments and test procedures that meet the prerequisites of the continuously changing requirements of power systems dominated by distributed energy resources (DER). Their work enables the provision of grid flexibility, accelerates innovative developments, and mitigates new and unforeseen error-modes by the verification of correct and stable operation of active components, systems and software controls that are critical for our future power systems.



Peter Vaessen DERIab Spokesperson 2014-2017 DNV GL



**Prof. Graeme Burt** DERlab Spokesperson as of 2017 University of Strathclyde

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126 Cooperative Papers

### Introduction

Electrical power systems and their control are facing a continuous transformation process. Nowadays, grid control is mainly based on large-scale power plants with synchronous generators. However, the share of grid-connected inverterbased generators is continuously increasing. In the future grid scenario of up to 100% shares of renewables, the active contribution of inverter-based generators to the grid stability and to the security of power supply becomes absolutely critical.

It is the task of DERlab and its members to address the power system stability and security challenges of the pan-European interconnected grid in the context of very high shares of renewable generation and to propose and test system services from such units for overcoming these challenges. These units integrating new control strategies need to be tested and proven under controlled and secured conditions that extended laboratory environments could provide by integrating advanced hardware in the loop and co-simulation based tools. Furthermore, in order to ensure a seamless grid connection of such units, the power system feedback to the different control strategies needs to be considered within the testing approach. For this purpose, the "power system testing" concept has been introduced and brought by DERlab into discussion at the international level. In this context, DERlab is coordinating the description and harmonisation of related testing procedures. As a next step, recommendations for the further development of the related regulatory framework have to be formulated and released. DERlab has already initiated activities addressing the aforementioned issues, as the different sections of the current Activity Report 2016/2017 show, and there is still a huge amount of work to be performed in this direction that DERlab and its members are committed to perform.

The first part of the DERlab Activity Report 2016/2017 documents the work of DERlab and its members in the form of international networking and knowledge exchange on the topic of smart grids operation, control and monitoring strategies. The second part presents an extensive overview of DERlab members' infrastructures with emphasis on power system testing. This chapter highlights research advances and infrastructure updates since the previous issue of the Activity Report and outlines DERlab members' prospective developments. Finally, we present a brief list of scientific publications released cooperatively by DERlab members in 2016-2017.



Dr. Diana Strauss-Mincu DERlab General Manager

### Nomenclature

CHIL Controller Hardware in the Loop **CHP** Combined Heat and Power **CVC** Coordinated Voltage Control **DER** Distributed Energy Resources **DG** Distributed Generation **DMS** Digital Measurement System **DSO** Distribution System Operator **DSM** Demand Side Management **EMSP** E-Mobility Service Provider **ESCO** Energy Service Companies **EVSEO** Electric Vehicle Supply Equipment Operator **EVSE** EV Supply Equipment FMI Functional Mock-up Interface FRT Fault Ride Through G3M Grid Management and Maintenance Master Framework **GHG** Greenhouse Gas HIL Hardware in the Loop **HVDC** High Voltage Direct Current I-V or (V-I) Current-Voltage LV Low Voltage LVRT Low Voltage Ride-Through **MPPT** Maximal Power Point Tracking **MV** Medium Voltage

**OEM** Original Equipment Manufacturer **OGEMA** Open Gateway Energy Management Framework PCC Point of Common Coupling **PHIL** Power Hardware in the Loop PID Controller Proportional Integral Derivative Controller **PID** Potential Induced Degradation **PLC** Programmable Logical Controller **PMU** Phaser Measurement Unit **PV** Photovoltaics **RES** Renewable Energy Sources **RI** Research Infrastructure **RTDS** Real Time Digital Simulator **RUE** Rational Use of Energy **SMX** Smart Meter Extention **SDK** Software Development Kit SGAM Smart Grid Architecture Model SRA Strategic Research Agenda TRL Technology Readiness Level **TSO** Transmission System Operator V2X Vehicle-to-Everything WECC Western Electricity Coordination Council

Photo by Dennis Schroeder, NREL

## International Networking Knowledge Exchange

### **ISGAN Leading Global Smart Grids Research**



#### Michele de Nigris

Director of Sustainable Development and Energy Sources (RSE)

Michele de Nigris received his Engineering degree in Electric Engineering from the University of Genoa (Italy) in 1983. He is Director Sustainable Development and of Energy Sources Department in RSE. He has been elected Chairman of the IEA Implementing Agreement ISGAN (International Smart Grids Action Network) at the first Executive Committee Meeting in Seoul in June 2011) and held this position till March 2017.

International leader in the study, research and testing fields on electrical components for more than thirty years, he has foreseen the strategic importance of the smart grids since their early application and has directed the efforts of his team towards cutting-edge technologies in this field.

Michele de Nigris is the Chairman of the Italian Standardisation Committee on Smart Energy Systems (CEI TC313) and the Italian Representative in the related CENELEC and IEC bodies. He also represents Italy in other international policy contexts such as the End Use Working Party of the IEA. He has been one of the prime movers of the Smart Grids Joint Programme of the European Energy Research Alliance (EERA).

Michele de Nigris is author and co-author of nearly 100 scientific papers, several of which published in high impact-factor reviews. He has been the Coordinating person of the European Coordination and Support Action GRID+ financed by the European Commission.

#### Interview with Michele de Nigris

### How do you see the evolution of ISGAN and its goals from its launch in 2010 up till now?

Since its creation in 2011, ISGAN has developed as the most important panel of inter-governmental collaboration in the field of smart grids. Its membership has progressively grown from 10 to 25 countries representing more than 90% of the global investments in the sector. The activities carried out by ISGAN Annexes spread along a very large range: from pure policy aspects to technological developments, interoperability, sustainability and societal aspects. Nowadays, ISGAN develops its activities along several main axes:

- survey of the drivers and activities in the different countries and the emergence of excellences and lessons learned that can show a global value for the community
- the analysis of the economic and financial implications of the deployment of smart grids
- the evolution of the state of the art of the technology and the related barriers and opportunities in the different regulatory and infrastructural contexts
- the interaction between the evolution of the energy system and that of the society
- the building up and maintenance of the required professional skills and
- the definition of protocols for testing of the performances and interoperability of the solutions developed

ISGAN is consulted and valued more and more. ISGAN publications are seen on the tables of ministries and important stakeholders. ISGAN reports are downloaded by thousands copies: this is not yet a "commercial best seller", but we are on the right path!



#### What is the ISGAN strategy on smart grid activities? How would you describe the ISGAN roadmap on smart grids research and its role in meeting the IEA's goals?

ISGAN must continue to develop and grow, both geographically and substantially: several countries have shown interest in becoming members of the ISGAN community: we will welcome them and value the contribution they can give to a global understanding of the potential of smart grids in a global context. ISGAN reports must become an even more appreciated reference for policy makers and a trusted source of inspiration for practitioners. ISGAN reports always consider a global view. The panorama of solutions, challenges and opportunities reflect situations with a very wide perspective: from very advanced and "smart" energy systems in operation to the situations where energy access and poverty are still a reality. In all these diverse situations ISGAN has some experience to show and some advice to offer ...and very much to learn!

Smart grids solutions can help integrating higher shares of renewables, thus contributing to the reduction on GHG emissions; they can foster energy efficiency and give the final user the tools to take an active role in the energy system, through his participation in an open and transparent energy market. Acting as a hub of knowledge for clean energy, ISGAN can take active part in this development and can be one of the catalysts of this energy transition, thus contributing to reaching the IEA goals.

### How does ISGAN see SIRFN's contribution to the progress on power system testing?

SIRFN is contributing substantially to the development of testing protocols for smart grids: the different parties and laboratories contributing to the activities of ISGAN-SIRFN exchange opinions, information, and experience about the testing of smart grids equipment and solutions. Intelligent inverters for PV applications and for the coupling of electricity storage have been successfully tested. The matter is addressed very rationally:

- The validity of the testing methodologies is considered at first, verifying that the stresses and the boundary conditions carefully represent the real field and that the right physical quantities are measured. In this context the basic testing protocols are studied to ensure that they are able to reproduce the most important phenomena influencing the performances of the smart grids solutions and functionalities addressed.
- The replicability of the procedures is addressed at the second stage. Its aim is to ensure that the test protocols are written according to high quality standards and that they can be replicated in the same laboratory obtaining results that are statistically valid and homogeneous.
- Finally, the reproducibility issue is considered to ensure that the specifications can be applied by different test operators in different laboratories and that similar results are always achieved.

This makes the future standard sound and solid and ensures the impact of the results and lessons towards the standardisation community.

What is in your opinion the added value that DERlab brings to SIRFN as an association of leading smart grids laboratories worldwide?

DERlab has a central role in Europe as an association gathering major stakeholders and laboratories on distributed energy resources. It has therefore a very important role and responsibility in the coordination of the developments carried out by its members leveraging the networking opportunity it offers. In the ISGAN community, DERlab can bring its experience to enhance the collaboration among laboratories that are very diversified in terms of infrastructures, capabilities and skills levelling on the excellence side the entire community. This requires dedication, time, professionalism and high networking capabilities - I am convinced that DERlab has them all.



### **SET-Plan Strategy on International**

### Collaboration



#### Andreea Strachinescu

Head of Unit New Energy Technologie and Innovation Directorate General for Energy (European Commission)

In the European Commission (EC) **Andreea Strachinescu** is responsible for the development of policy and actions on non-nuclear energy research and innovation. The core topics she is in charge of are Strategic Energy Technology Plan (SET-Plan), the energy research and innovation strategy of EU and H2020 – the main financing instruments of research and innovation at EU level.

Ms. Strachinescu studied mechanical engineering and business administration in Bucharest, Romania and obtained her Master of Science degree in International Affairs from H.E.C. Montreal, Canada.

Prior tojoining the European Commission, Ms. Strachinescu professional activity was in the public service in the field of economic development and international cooperation, trade policies and actions.

#### Interview with Andreea Strachinescu

### How does the SET-Plan's strategy support the EU 2030 Climate and Energy Objectives (EU28 INDC)?

The SET-Plan is the research and innovation pillar of EU policy. In the last decade it has highly contributed to driving down the costs of low carbon technologies and highly improving their performance. Those factors, along with the favourable legislative framework that was put in place by the EU, lead to the significant increase of the respective investments and of the deployment volumes, especially regarding solar and wind technologies. As a result, the EU is very much on track towards the achievement of the 2020 targets (for the penetration of renewable energy, for energy efficiency and for the emission reduction targets) and is expected to further contribute to the respective 2030 objectives.

For the decade to come, the new challenges for the energy system will mostly have to do with a cost-effective and secure integration of the RES into our energy system, but also with the consumer being an active player in this transformation. The integrated SET-Plan has adapted to those new needs by putting a new focus on how low-carbon technologies can be integrated into the energy system. The targets that have been set in all 10 SET-Plan actions represent ambitious cost reduction and improvement of performance objectives in low carbon technologies. Current work focuses on how to implement the targets by aligning efforts and promoting synergies in identified, impactful R&I actions. This shows that SET-Plan is totally focused on delivering the results that will drive forward the EU's 2030 framework for climate and energy policies, more fuel savings, more innovation that will result in more jobs & growth.

# How does the SET-Plan address the entirety of the research framework - from incipient innovation through to integrated research and eventually market integration - both in terms of financing and regulations?

The SET-Plan addresses innovation challenges all along the innovation value chain from lower TRLs till higher TRLs solutions. This is ensured from the participation of various actors in the SET-Plan consultations, which represent universities (this would cover basic research), research institutes (for medium TRL R&I solutions), but also actors from the industry that are mostly interested in more "mature" innovative solutions that are closer to market entry. The SET-Plan actors also include participants such as KIC-InnoEnergy that bridge the different TRL levels and guide the different actors in terms of suitable financing and regulations. A practical example was the SET-Plan Integrated Roadmap, published in November 2014, where the SET-Plan actors proposed a wide list of actions and projects, starting form basic research, towards demo projects, industrialisation and market uptake, including an estimate of funding needs and timelines. The work that now begins in the Temporary Working Groups of the SET-Plan to implement the targets of the 10 SET-Plan actions, will include proposals for research and innovation actions in all levels of the value chain, but also will focus on identifying the most relevant funding mechanisms for projects and measures to address regulatory issues.

### How do public consultations play a role in forming research programmes for Europe?

For policy and legislative initiatives, the European Commission has a procedure for public consultations. In addition to that we have forums to discuss with member states and stakeholders. The key element in those are the SET-Plan Steering Group, the European Technology and Innovation Platforms (ETIP) and of course the Programme Committee for H2020 Energy.

#### How do you see the mission of international associations of research, academia and industrial laboratories in contributing to the SET-Plan implementation?

The ambitious energy transition that is necessary to meet energy and climate change objectives cannot be done only with technologies of today. Research, academia and industrial laboratories need to develop the science and technology base for this. DERlab has a key role in developing testing procedures and protocols through pre-competitive and pre-normative research that will support the transition towards more decentralised power generation. SET-Plan is foremost an EU-led initiative, addressed at the EU community of stakeholders and member states. This is why international research or academia associations were not directly associated with the initiative up till now. On the other hand international associations of research and academia are not excluded from participating in the SET-Plan.

Especially now, the participation of the EU and of several SET-Plan members in Mission Innovation Initiative has brought a new international dimension to the SET-Plan. Their know-how and structure serve as a model for the development of the Initiative. This being said, international academic or research platforms, industrial umbrella organisations and other international instances can heavily influence the work and deliberations of the immediate actors of SET-Plan, through their ongoing concerted work, activities, research programmes, the focus they maintain on certain policy questions and the interests they represent. The gradual development of the Challenges under Mission Innovation and the relevant exchanges with the SET-Plan, is expected to deliver a new dynamic to the international dimension of the SET-Plan.

#### How can the smart grids and research community address the European research needs to come up with substantiated response in research proposals?

It is always important to understand the policy context for the research needs identified by EU member states and the European Commission. The SET-Plan provides a strong base for this. Through SET-Plan, smart grid and research communities have a role to play to help define the scope and tackle the main obstacles for more cost-efficient, cheaper and cleaner solutions. The relevant European Technology and Innovation Platform on Smart Networks for Energy Transition (ETIP SNET), for example, can influence the body of work undertaken within SET-Plan. They exploit limitations of smart grids capabilities or research means and objectives and also provide collateral thinking to drive innovative solutions forward. They have experience of the reality on the ground, which they can offer to form competent decisions within the SET-Plan deliberation process. The next step is to build up good consortia with relevant expertise that based on innovative ideas can create proposals with high impact. Smart grids and DER research community promotes through their networking events an excellent platform to build up such proposals and this will also be one of the tasks of the Temporary Working Group on Smart Energy Systems under SET-Plan action 4.

# How is the European Commission involved in global research initiatives? How does the EC play a role in ISGAN and IEA?

The EC, on behalf of the EU, recognises the importance of global action for energy research and plays an active role in international R&I efforts. It is a member of major international organisations in the field of clean energy like IEA, Clean Energy Ministerial, Mission Innovation, IRENA, to name a few. It has been an active member in IEA for quite some time, facilitating it to take up secretariat duties or carry its research and report capabilities in the field of energy and energy research in particular. Specifically for smart grid projects, the EC furthers the objectives and work programme of ISGAN, and promotes the deliverables out of its research efforts in this particular field, by also being an ISGAN participant. We see ISGAN playing a role in promoting the best practices and excellent results that smart grid projects have achieved. And finally let's not forget the substantial support the EC offers to global research initiatives through its research programmes such as FP7 and H2020, and the specific strand of H2020 dedicated to international energy projects.

SET-Plan aims to accelerate progress in key aspects of enabling current technologies and solutions in the clean energy sphere. It seeks to render energy technologies cheaper, faster, and make them simpler, easily applicable, more efficient. It is a driver to innovation, by enabling the coordination of research efforts within the EU to flourish and arrive at a substantial outcome. This is the reason that SET-Plan welcomes the input of whichever global research actor that can contribute to this process and facilitate knowledge sharing in this filed, or drive innovative solutions further. The vast array of sectors and technologies that SET-Plan covers can also allow it to be a partner to a number of divergent similar initiatives around the world and try and boost existing or nascent international efforts in the fields that it covers. SET-Plan - through its members - is seeking to engage with the international research community, to maximise synergies. SET-Plan would be keen to collaborate and form strong cooperative ties with existing similar platforms to drive clean energy innovation forward. And in addition, it can bring its valuable experience in the coordination of national energy research programmes into the workings of other initiatives, such as Mission Innovation.

### EERA JP SG Addressing Research Perspective in Europe



Luciano Martini

Director of Transmission and Distribution Technologies, RSE Spa

Luciano Martini has 25 years' experience on Research & Development activities dealing with renewable energies, applied superconductivity, and smart grids. He is the Coordinator of the European Energy Research Alliance (EERA) Joint Programme on Smart Grids, which includes 33 research organisations representing 16 European countries, and of the European Integrated Research Programme on Smart Grids (ELECTRA). He has been repeatedly recruited by organisations as the European Commission and the US DOE as an independent expert to review research proposals and publicly funded R&D projects.

Luciano Martini is the vice-Chairman of the Executive Committee of the International Energy Agency (IEA) Technology Collaboration Programme for Smart Grids (ISGAN) and Chairman of a "Co-operative Programme for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector", and member of several CIGRE and IEC international working groups. Martini is an official member of the EEGI-Team and of the <u>ETP SmartGrids Steering Committee.</u>



#### Luciano Martini

At present, R&D activities in the field of smart grids are not entirely coordinated across the whole Europe, as there naturally is a tendency for institutes and companies to choose to perform studies and develop technologies most aligned towards the objectives of their member state, as well as own priorities, capabilities and interests. This situation is not optimal since it leaves some research activities receiving less focus than others.

European alignment and collaboration across technological and geographical borders in the energy sector is key, and the European Energy Research Alliance (EERA) is one of the actors. In line with the EERA approach, the Joint Programme on Smart Grids (JP SG) operates in order to coordinate a great part of major European research organisations' R&D efforts on smart grids towards common European goals, the SET-Plan targets and hence the EU 2030 Climate and Energy Objectives.

In fact, the JP SG, by means of the extended cross-disciplinary cooperation involving at present 40 research organisations with different and complementary expertise and facilities, aims to address, in the mediumand long-term research perspective, the most critical areas directly relating to the effective acceleration of smart grid development and deployment. At present, the research activity of the JP SG - that integrates activities and resources combining national and European sources of funding - is structured around five specific Sub-programmes and a number of Coordination Areas and Tasks. The main focus is devoted to active distribution network, integrating distributed generation from renewable energy sources, information and communication technologies and interoperability issues, electrical storage systems, and transmission networks.

In the past few years the activity of the JP SG has been strongly supported by several European research projects as for example ELECTRA IRP (the integrated research programme on smart grids), ERIGrid that addresses the specific aspect of smart grids system validation by means of outstanding research infrastructures, and the newly launched Intensys4EU project supporting the work of the European Technology & Innovation Platform on Smart Networks for the Energy Transition (ETIP SNET). Moreover, the effectiveness of the JP SG activity has been further enhanced by the establishment of much closer relationships and collaborations with key European stakeholders as ENTSO-E, EDSO4SG, ERANet SG+, EASE, and others.

We believe that the European energy systems are key enablers for sustainable future, for battling climate change and for ensuring industrial growth and prosperity. Smart grids are certainly an integral part of this and a stronger, smarter, more efficient electricity infrastructure will support growth in renewable energy production. Thus we can cut carbon pollution, empower consumers to know and manage their energy use, and lay the foundation for sustained, longterm economic expansion, thus helping to ensure that Europe maintains its position as a global leader in innovation and technological advancement.

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JRC, Ispra (IT), 4-6 April 2017



# Consolidating European Smart Grid Infrastructures

## Integrating State of the Art Laboratories

The integration of RES - as key enablers for reduction of greenhouse gas emissions into the power systems - has increased over the past years and led to higher complexity of electric power systems. The increased availability of advanced automation and communication technology, along with novel intelligent solutions for system operation has transformed the traditional power system into a cyber-physical energy system - a smart grid.

Research activities so far have mainly focused on validating certain aspects of the smart grid. However, a holistic and integrated approach for analysing and evaluating such complex system has not been developed yet. The ERIGrid project aims to support the technology development and rollout of smart grid approaches, solutions and concepts in Europe by addressing the aspect of system validation for smart grids and developing common methods, concepts and procedures by integrating eighteen European research centres and institutions with outstanding research infrastructures.



#### Power system testing and co-simulation

Within the ERIGrid project partners develop holistic and integrated validation and testing procedures for smart grid configurations through the following steps:

- structured analysis, comparison, and adoption of existing procedures for testing, prototyping and validation applied in various other domains (e.g., automotive, aerospace); analysis of the Design of Experiments (DoE) approaches for the above-mentioned domains that allows for the modelling of simplified yet valid black-box models
- subsequent gap analysis that contrasts the state of the art with the requirements for the ERIGrid approach

ERIGrid partners are mapping out ERIGrid research infrastructure capabilities in order to specify which partner is able to conduct a specific experiment or simulation. Partners are also developing a holistic approach that allows for an efficient distribution of large-scale integrated scenarios across multiple laboratories.



**ERIGrid**: European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Rollout

#### Duration:

November 2015 – 30 April 2020 **Funding**: RIA - Research and Innovation action; H2020 grant agreement no. 654113 **Partners**: 18 partners, including DERlab Office

#### www.erigrid.eu



at DER test facility of RSE

#### DERlab members in ERIGrid:

#### Further areas of focus in ERIGrid:

- co-simulation based assessment methods: developing advanced simulation based methods to check and validate given smart grid scenarios, configurations and applications
- integrating commercial and open-source modelling and simulation frameworks, both specialised on particular system aspects (e.g., power system simulator, communication system simulator) and universal (e.g., general physics modeller, Matlab / Simulinik- or Modelica-like environments)
- integrated laboratory based assessment methods: enhancing the available laboratory possibilities to develop and set up an integrated research infrastructure approach supporting system-level analysis of components and small-scale systems.
  - Further development of HIL methods
  - Improvement of existing laboratories with ICT systems, technologies, protocols, etc. (e.g., IEC 61850, CIM, SIA, metering standards, cyber-security standards)





























## **Open Access to Leading Smart Grid Facilities - Free of Charge**

To engineers from research, academia and industry, ERIGrid provides access to Europe's leading smart grid and DER facilities - free of charge - within the **ERIGrid Transnational Access programme.** 





D-NAP laboratory of the University of Strathclyde



Providing access to world-leading research facilities, ERIGrid offers a unique opportunity to academic research groups, SMEs and other smart grid actors who cannot always afford access to high-level scientific infrastructures.

The provided facilities of ERIGrid partners allow successful applicants for the Transnational Access to perform a detailed characterisation of smart grid components as well as testing and validation of small-scale system configurations like microgrids. The focus of the ERIGrid Transnational Access programme is on laboratory experiments which are more suitable for characterising components and small-scale systems, but co-simulation and HIL are also applicable.

Furthermore, validation and testing of large-scale smart grid configurations are possible in ERIGrid laboratories. Therefore, the focus of the ERIGrid Transnational Access is on using co-simulation and HIL approaches together with laboratory equipment – if necessary – in a combined manner allowing a more detailed analysis of a specific smart grid configuration.











## Impact

#### Collaboration with the smart grids community and dissemination:

- Provision of access to harmonised research infrastructure services • and integrated research infrastructures supporting component characterisation, small-scale and large-scale systems validation
- Supplying training & education material that addresses smart grid systems issues
- Raising awareness of smart grid validation needs by broad • collaboration with stakeholders

#### Smart grids research:

- Identification and analysis of smart grid testing and validation cases •
- Advanced co-simulation based validation methods
- Assessment methods for ICT / automation system analysis
- Advanced laboratory based validation methods
- Possibilities to connect research facilities and perform joint experiments ٠

#### Access to research infrastructure:

Provision of external industrial & academic users with access to • extensive research infrastructure services



Multipower laboratory of VTT





Systems Laboratory of NTUA



PV Systems Laboratory of CRES

Contributing to reaching SET-Plan objectives, ERIGrid in particular addresses the **H2020-INFRAIA-2014-2015 work programme** topic "Integrating and opening existing national and regional research infrastructures of European interest":

- By integrating 18 major European institutions from 11 European countries with major smart grid related research infrastructure, ERIGrid realises the flagship initiative of the Innovation Union expressed in Commitment n. 4: 'Opening of member state operated research infrastructures to the full European user community'.
- External researchers have wider, simplified, and more efficient access to the best research infrastructures they require to conduct their research, irrespective of their location. They benefit from an increased focus on user needs.
- ERIGrid supports education of a new generation of researchers exploiting the essential tools developed in the project for conducting state of the art research.
- Related operators of research infrastructures offer improved and harmonised services.

- Closer interactions among larger number of researchers and infrastructures lead to wider sharing of information, knowledge and technologies across fields and between academia and industry.
- Reinforced partnerships between research institutes and industry foster innovation.
- The integration of major scientific equipment or sets of instruments and of knowledge-based resources (collections, archives, structured scientific information, data infrastructures, etc.) leads to a better management of the continuous flow of data collected or produced by these facilities and resources.



DER Test Facility of RSE



ERIGrid harmonises the virtual entry point for system-level analysis based on the experiences from the component-oriented research infrastructure projects DERri and SOPHIA. By doing so, ERIGrid ensures operational impact: harmonised system-level validation and testing in the medium term and sustainable development of European smart grid research infrastructure in the long term.

By creating a significant impact on Europe's power system industry ERIGrid will reinforce Europe's smart grid technology leadership. ERIGrid results will give new dynamics to the European smart grid research and provide the material for converging on common standards and technologies with other parts of the world with Europe in the lead.



#### Ata Khavari, member of the DERlab project team:

"Testing is an essential stage in the development. So far, testing approaches in the context of power systems have had a focus on individual components. Meanwhile through power system modernisation and its increased coupling across other domains, such as ICT and heat, the need for a standardised and holistic methodology for testing such complex and automated system is sensed more than before.

Demand response is an excellent example of a multi-domain system functionality. Several tools such as smart meters, smart home appliances, advanced monitoring and control platforms for DSOs and



aggregators as well as their interactions should be validated and tested as a whole pack before integration into the real system. The current methodologies for testing such system are mainly based on virtual approaches (simulation and HIL), which may provide not very accurate results. ERIGrid aims to not only develop the current virtual testing methodologies (develop co-simulation approaches) but also to develop harmonised approaches for combining virtual and non-virtual experiments as well as multi-lab tests that lead to more accurate test results and savings in time and costs."





SIMULATED SYSTEM / COMPONENTS REAL SYSTEM / COMPONENTS SIMULATED SYSTEM / COMPONENTS Communication **Power System Analysis** Components REAL SYSTEM / COMPONENTS REAL SYSTEM / COMPONENTS Power Grid Generators, Storages, **Electrical Signals** Loads, etc. -Power, Voltages + Control ÷ ................. .... Signals ..... SCADA / DMS / HMI SIMULATED SYSTEM / COMPONENTS **Control System** SIMULATED SYSTEM / COMPONENTS Power Quality, etc. Control Center Central Control 88 10 88 Measurements IED Local Control Parameters here here 1 ----Local Control REAL SYSTEM / COMPONENTS SIMULATED SYSTEM / COMPONENTS REAL SYSTEM / COMPONENTS

Smart grid validation approaches using virtual and real components





#### **DERIab network in ERIGrid**

Most of the ERIGrid partners and their laboratories are DERlab members, providing valuable expertise in development and evaluation of different aspects of smart grid configurations. The ERIGrid consortium thus had useful information about the current testing and evaluation methods and procedures, as well as research infrastructure needs and requirements for performing different types of tests.

ERIGrid partners then analysed this information and identified the gaps in order to develop a holistic and integrated validation and testing procedure for smart grid configurations.

All the DERlab members involved in ERIGrid as partners provide open access to outstanding research infrastructures in the field of smart grid systems and DER to external users - within the Transnational Access programme (see p. 16).

#### Services

DERlab members involved in ERIGrid offer a range of services to external companies outside the project:

- DERlab members will be able to perform highly sophisticated, harmonised and integrated experiments thus offering improved research infrastructure services - due to the developed holistic and integrated validation and testing procedure for smart grid configurations in ERIGrid.
- In 2020 DERlab together with all other ERIGrid partners will publish a white book on power system testing, including the research achievements and experiences from the ERIGrid Transnational Access user projects. This book will present the overview of developed holistic system integration and testing procedures as well as developments on co-simulation based assessment methods and integrated laboratory-based assessment methods.
- Several DERlab members including AIT, CRES, DTU, G2Elab, ICCS, Fraunhofer IWES and the University of Strathclyde train and provide education material to power systems and ICT professionals, researchers and students in the field of smart grid systems (smart grid operation, validation / testing, rollout scenarios). Through this activity, the project partners connect professionals working on power systems and ICT.

Smart Grid Technologies Laboratory (SGTL) of TECNALIA



#### **Partnerships**

Already in the early stage in the project, the ERIGrid partners established cooperation with eight EU-funded projects (ELECTRA IRP, SPARKS, SmartNet, SmarterEMC2, NOBEL GRID, MIGRATE, SALVAGE and SmILES), seven national projects, three networks (EERA JP Smart Grids, IEA ISGAN/SIRFN and MEAN4SG), two platforms (FUTURED and openKONSEQUENZ), and one initiative (Power Cybernetics), which are all dealing with different smart grids aspects. These activities have already brought mutual benefits, such as:

- Several reference smart grids scenarios and use cases from partner projects were used as an input for the ongoing research in ERIGrid.
- ERIGrid partners acquired information about current testing and validation methods for smart grid systems as well as research infrastructures needs and requirements for performing different types of tests in the scope of smart grids.
- Expected during the whole runtime of ERIGrid is the information exchange on ERIGrid testing methodology development based on ongoing research achievements.
- External users active in partner projects have the possibility to access ERIGrid facilities and benefit from the harmonised testing procedures on the topics that ERIGrid covers.



University of Strathclyde



DER test facility of RSE







Thomas Strasser

Coordinator of the ERIGrid project, Senior Scientist Electric Energy Systems, AIT

Thomas Strasser works as a Senior Scientist at the AIT Austrian Institute of Technology in the field of Electric Energy Systems of the Center for Energy. He holds a PhD degree from Vienna University of Technology. His main responsibilities at AIT are the strategic development of the research area smart grid automation and control architectures, the coordination and management of national and international research projects as well as the advice of junior scientists. Prior to that he worked as a researcher for PROFACTOR in the realm of advanced and reconfigurable automation and control systems for more than six years.

Thomas Strasser has been involved as scientific and sub-project coordinator in several national and international research projects. In addition, he is an evaluator of R&D proposals/projects and member of several IEC and IEEE standardisation working groups. He is also a senior member of IEEE, involved in several IEEE technical committees and task forces and serves as an associate editor of scientific journals.

He is a lecturer at the Vienna University of Technology and a Guest Professor at the University of Applied Sciences Salzburg in the area of automation and ICT systems as well as smart grids.

# Shaping the Concept of European Integrated Smart Grid Infrastructures

#### **Interview with Thomas Strasser**

How do you evaluate the contribution ERIGrid is making to the smart grids progress and community? What is the added value of the ERIGrid project in the context of advances in smart grids? What is the pioneering, innovation element to ERIGrid?

Renewable energy sources are key enablers to decrease greenhouse gas emissions and to cope with the anthropogenic global warming. The intermittent behaviour of them and their limited storage capabilities present new challenges to power system operators in maintaining power quality and reliability. However, the increased availability of advanced automation and communication technologies has also provided new intelligent solutions to these challenges. Previous work has presented various new methods to operate highly interconnected power grids with corresponding components in a more effective way. As a consequence of these developments the traditional power system is transformed into a cyber-physical system, a smart grid. Previous and ongoing research activities have mainly focused on validating certain aspects of smart grids, but until now no integrated approach for analysing and evaluating complex configurations in a cyberphysical systems manner is available.

The lack of system validation approaches for smart grids is especially addressed by ERIGrid. By providing a pan-European research infrastructure ERIGrid supports the technology development as well as the rollout of smart grid solutions and concepts in Europe. It tackles a holistic, cyber-physical systems based approach by integrating 18 European research centres and institutions with outstanding research infrastructures and jointly develops common methods, concepts, and procedures. ERIGrid also integrates and enhances the necessary research services for analysing, validating and testing smart grid configurations. System level support and education for industrial and academic researchers is provided as well in ERIGrid to foster future innovation. ERIGrid aims to come up with a holistic validation and testing procedure for smart grid configurations. Where do you see specific challenges in this extensive mission? How does ERIGrid tackle them?

The main challenges in the project are related to the first-time development of a holistic validation procedure and corresponding tools covering smart grid systems (power system and ICT/automation system) in a comprehensive way. ERIGrid tackles these challenges by the cooperative work of selected first-class partners from power system and ICT/ automation domain. Researchers and engineers from both areas are closely working together to find a proper solution.

The main research and educational activities are related to:

- Definition of harmonised and possibly standardised validation and testing procedures
- Development of integrated methods and corresponding tools covering power and ICT topics of smart grid configurations in a holistic manner
- Development of benchmark criteria for system level tests
- Provision of advanced research infrastructure possibilities and corresponding services
- Education of professionals, engineers and researchers which are able to understand smart grid configurations in a cyber-physical manner

### How does ERIGrid make use of the available data in smart grids? How does ERIGrid deal with the state of the art in smart grids?

The ERIGrid consortium is composed of well-known, first-class European research institutions and companies active in the domain of power systems / smart grids. Those partners have a long tradition of working together in various projects and initiatives like DERIab, EERA Joint Programme on Smart Grids, IEA ISGAN/SIRFN. There is a comprehensive set of knowledge already available, which is very important in order to achieve the highly challenging ERIGrid goals and objectives.

#### What technical advances will ERIGrid make in smart grids?

The main goal of the ERIGrid project is to support the technology development as well as the rollout of smart grid approaches, solutions and concepts in Europe considering a holistic, cyber-physical systems approach. It integrates the major European research centres with a considerable, outstanding smart grid research infrastructure to jointly develop common methods, concepts, and procedures. It also integrates and enhances the necessary research services for analysing, validating and testing smart grid configurations. ERIGrid also aims to foster future innovation by providing system level support and education for industrial and academic researchers in smart grid research and technology development.

### How does ERIGrid play a role in shaping the concept of the integrated European smart grid and DER research infrastructure?

ERIGrid addresses these challenging aims by providing a single entry point to the research infrastructures of project partners and offering a broad spectrum of services to researchers active in smart grids. Compared to past energy-related research infrastructure projects like DERri or SOPHIA, ERIGrid is the first project which focuses on smart grid system level questions – covering power and ICT topics in an integrated manner. This will strengthen the technical leadership of Europe in the energy domain.

#### What is the long-term benefit of focusing on the continent-scale network of RIs?

The long-term benefits can be summarised as:

- Integration and harmonisation supporting smart grid validation: ERIGrid further harmonises the virtual entry point for systemlevel analysis based on the experiences from the component-oriented research infrastructure projects DERri and SOPHIA. By bringing together the major existing European research platforms in the field of smart grids, ERIGrid contributes to structuring the European research area on a large scale, ranging from integrating renewables, ICT and cyber-security solutions up to systemlevel testing. Furthermore, European researchers (industry and academic) will have greatly improved access to the best research infrastructures.
- Harmonised system-level validation and testing: ERIGrid will have a structuring impact on the daily operation of the partners' research infrastructures. The foreseen networking activities will improve the current situation with the lack of standards for emerging technologies and common grounds for interoperability allowing to answer system-level questions.
- Sustainable European smart grid research infrastructure: With the integrated research infrastructure, a long-term cooperation of the partners will continue and therefore ensure the encouragement of new ideas for a faster innovation process and improved scientific output in the smart grid domain.



Moreover, best practices will be exchanged and expertise will be integrated by the synchronisation of background and promotion of transregional and cross-cooperation. The industrial partners in ERIGrid see the cooperation with the academic partners as a chance to generate new knowledge that gives them a head start in the development of a technology highly demanded by the European power system and smart grid market. The teamwork among industry partners strengthens the technology absorption patterns as both of those partners successfully work in networks. Academic partners see the chance to continue a successful long-term cooperation in smart grid research. Cooperation with the industry partners gives access to technologies and challenging applications and fosters the realisation of innovations in the smart grids domain – which is a European need.

#### How does ERIGrid fit in the changing smart grids landscape?

Up to now there was no integrated approach available for analysing and evaluating smart grid configurations addressing power system, and information, communication and automation/control topics. Cyber security and privacy issues are not sufficiently addressed by existing solutions either. In order to guarantee a sustainable and secure supply of electricity in a smart grid system with considerable higher complexity as well as to support the expected forthcoming large-scale rollout of new technologies, a proper integrated and pan-European research infrastructure for smart grids is necessary. ERIGrid is addressing this issue by providing an infrastructure supporting system-level analysis, evaluation and testing of smart grids.

#### How will ERIGrid help overcome today's challenges in smart grids and DER?

Power system operation is of vital importance, and it has to be developed far beyond state of the art to meet the challenges ahead. In fact, nearly all European countries are facing a rapid and very important growth of renewable energy sources such as wind and photovoltaic that are intrinsically variable and up to some extent difficult to predict. This fact has increased the level of complexity of system operation. To avoid dramatic consequences, there is an urgent need for system flexibility increase and full implementation of smart grids solutions such as information and communication technology and power electronics based grid components. In order to address these challenges the project provides a cyber-physical, multi-domain approach for analysing and validating smart grids on the system level covering power and ICT issues in an integrated and holistic manner.

#### How does ERIGrid address the topics of power system testing, common testing procedures, co-simulation?

Current developments in the field of smart grids show that future systems will contain a heterogeneous agglomeration of active components often based on power electronics and passive network components coupled via physical processes and dedicated communication connections with automation systems (SCADA, DMS) and advanced metering/ measurement systems. Also new applications and services are under development helping to fulfil future requirements and needs.

In order to analyse and evaluate such a multi-domain configuration, a set of corresponding methods, procedures, and corresponding tools are necessary. Usually, purely virtually based methods are not enough for validating smart grid systems, since the availability of proper and accurate simulation models cannot always be guaranteed (e.g., inverter-based components are sometimes very complex to model or it takes too long to obtain a proper model). Simulation and lab-based validation approaches have to be combined and used in an integrated manner covering the whole range of possibilities and challenges. Such an approach is necessary when tackling system level integration and validation issues. The following figure sketches this idea realised in ERIGrid: a flexible combination of physical components (available in a laboratory environment) and simulation models are combined in a flexible way depending on the corresponding validation or testing goal. This approach requires the improvement of available methods, tools and proper interfaces, which are currently being developed in the ERIGrid project.



How does ERIGrid collaborate with other European projects and global international networks (e.g. SIRFN, GSGF, etc.)?

Power system related topics have to be addressed on the European level through interconnected national power systems in Europe. Therefore, ERIGrid is teaming up with other European initiatives, projects, associations, and relevant stakeholders. Those collaborative activities are being used to exchange and collect information on relevant smart grid scenarios, use cases, research infrastructures requirements, and testing and evaluation needs and corresponding methodologies. We have already established links with such important projects and activities like ELECTRA IRP, SPARKS, SmartNET, NOBEL Grid, EERA Joint Programme on Smart Grids, and IEA ISGAN/SIRFN.

### How does the ERIGrid approach address SET-Plan's goals and the EU 2030 Climate and Energy Objectives (EU28 INDC)?

In order to achieve the targets of SET-Plan, we need more accessible and interoperable research infrastructures on the European level to support the technology development and future innovation as well as the needs of the European power system industry. ERIGrid contributes therefore to the SET-Plan objectives by providing a single entry point for system level validation and testing of smart grid systems and the provision of corresponding methods and tools.



ERIGrid Transnational Access (TA) is a researcher exchange programme provided by ERIGrid to industry, academia, and research users. How does this knowledge exchange format help reach ERIGrid goals?

The TA programme enables academic research groups, SMEs and other players in the smart grid field, who cannot always afford the use of these high-level scientific infrastructures, to access world-leading research facilities. This will also strengthen the links between academic and technological research thus speeding up the innovation process. It is anticipated that the TA requests and survey of user

needs will in some cases highlight gaps in the provided services and infrastructures of the ERIGrid consortium members. These inputs will be important indications for prioritising further development needs which will be addressed in ERIGrid.

### How does ERIGrid complement or compare with other researcher exchange programmes?

The ERIGrid TA is special in a sense that it is not really a pure researcher exchange programme. The core element is the free access and usage of the partners' research infrastructure (i.e., power system / smart grid laboratories) for corresponding experiments of external user groups. This means researchers and researcher groups from academia and industry can use first-class laboratories for their research and technology development work. Moreover, they also get support in their research work from the hosting organisation (i.e., the provider of the corresponding smart grid laboratory).







D-NAP laboratory of the University of Strathclyde

How else does ERIGrid involve the external smart grid community? What is the role of industry in this involvement?

ERIGrid developments and innovations will support the technology development and rollout of smart grid solutions, applications and corresponding services and therefore support the European power system industry. From the project point of view it is important to interact with potential stakeholders. ERIGrid has set up its own stakeholder group for collecting information on needs and requirements and receiving feedback from stakeholders as early adopters of the project innovations. This stakeholder group consists of research institutions/academia, power system industry, energy utilities, associations/networks, standardisation bodies, and public institutions.

At the end of the project - in order to support further development and innovation in the smart grid domain - ERIGrid will consolidate requirements, harmonised procedures and possibilities (i.e., research infrastructure services) on the topic of system integrated testing procedures. This effort will be outlined in the reference publication "European White Book on Power System Testing". Can you give a short statement about this publication?

The white book on power system testing is one major outcome of the ERIGrid activity. It will include a summary of the achieved ERIGrid research and technology developments related to system level testing including guidelines, corresponding methods and tools as well as best practices. It should become an important, future reference publication for researchers and engineers guiding them through the topic of holistic validation of smart grid configurations.

"We intend to make the innovative methods, concepts and processes developed within this top-class network of project partners available to other interested researchers, industrial enterprises, system operators and standardisation institutions. By networking European smart grid research infrastructure through the ERIGrid project, we are driving technological developments and the creation of intelligent networks in Europe."

- Thomas Strasser



### NOBEL GRID: From Lab to Business

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.

Focusing on residential customers, NOBEL GRID involves grid operators, energy service companies, energy providers and retailers, renewable cooperatives and aggregators. They all are interacting and actively using the flexibilities of customer-side electric loads and generators for optimising their business on the unbundled market.

Technically, the actors are supported by four different elements which are all newly developed in the project:

- An Energy Management and Analysis App (EMA App) for ESCOs and prosumers visualises and analyses the client's energy usage, and also allows for advanced functions like neighbourhood trading of energy.
- A Demand Response Flexible Market Cockpit (DRFM) exposes the flexibility provided by controllable loads and generators at the customer premises towards aggregators, ESCOs, retailers, and grid operators.
- A Grid Management and Maintenance Master Framework (G3M) for grid operators allows for detailed supervision and control of the energy system down into the low-voltage level. It integrates into and extends existing SCADA systems.
- A low-cost extended smart meter (SMX) for the prosumers serves as a pivot point for data transmission, handles wide-area networks access to the prosumer's local area components, serves as a firewall for the prosumer, and allows for extension with third-party smart home applications.

The technical components all work together in order to technically, economically and ecologically optimise operation of the energy system. An example is the avoidance of grid congestions. Here, the G3M exchanges standardised data with the DRFM, which in turn carries out demand response campaigns with automatic management of customer loads carried out by the SMX. The operation is supported by sophisticated functions which allow for real-time prognosis and simulation of the demand response effects onto the network. Also, customers get informed about campaigns by the EMA App, being incentivised and transparently reimbursed for their participation. Close-to-market solutions, usage of modern standards and methodologies, and cost efficiency due to the usage of open source solutions are key factors that make the project special. For example, off-the-shelf embedded systems like the BeagleBone Black Industrial are used as core component of the SMX.

The project results are tested not only in partners' laboratories but also in real life at five pilot sites all across Europe: Alginet (ES), Manchester (UK), Flanders (BE), Terni (IT) and Meltemi (EL). Different aspects and high-level use cases will be tested at these sites.

NOBEL GRID has released multiple publications, developed a smart grid architecture definition based on SGAM, and supports parts of the OGEMA release 2.1.0. and OGEMA SDK, both developed by Fraunhofer IWES (ogema.org). Fraunhofer IWES aims to promote OGEMA as an SMX rapid software development platform.

#### **NOBEL GRID**: New Cost Efficient Business Models for Flexible Smart Grids

Duration:

January 2015 – June 2018 **Funding**: H2020 grant agreement no. 646184, Integrating Activity (IA) Partners: 21 partners, including **DERlab** Office

#### www.nobelgrid.eu











# DERlab

#### DERlab network in NOBEL GRID

**Fraunhofer IWES** provided its IT subnetwork for testing small-scale embedded systems in NOBEL GRID.

Planning to publish the OGEMA SDK towards external developers, after successful project completion Fraunhofer IWES will promote OGEMA and OGEMA SDK as a tailor-made toolbox for rapid development of SMX applications. This presents particular interest since the SMX may be rolled out onto the European market.

**AIT** is involved in the project with its Safety & Security Department, contributing with broad experience in the field of secure smart grid architectures. AIT has carried out cyber-security testing of the SMX and has developed a tool to support the implementation of the Data Protection Impact Assessment template for Smart Grid and Smart Metering Systems.

**ICCS of NTUA** is operating the project pilot site in Meltemi (EL) - a seaside holiday building site with small houses inhabited during certain months of the year. It has the character of a microgrid and features various distributed resources (controllable loads, PV, diesel generator, battery systems, etc.) It has been extensively used in different R&D projects on microgrids and energy management as a testing site and a "living lab".

Moreover, ICCS has designed and developed within the NOBEL GRID project models and power interfaces to control distributed storage systems as well as a rapid prototyping design process for power conversion applications. ICCS also developed a three-phase power flow analysis tool considering the comprehensive formulation of all distribution network elements. ICCS also contributed to BRIDGE activities on behalf of the NOBEL GRID project.

**DNV GL** participates in the project as a provider of smart grid solutions, service development and RES certification for ESCOs and DSOs. DNV GL aims to further develop and test the Universal Smart Energy Framework (USEF). DNV GL develops standards and verification services for smart grids using the USEF to complement other existing verification services, for example, for ancillary services to TSOs.

DNV GL also expands its consultancy services on smart grids and associated topics like data management and smart grid services, for example, historical data filtering and cleansing.

In the project, the electrical energy and power systems group of the **University of Manchester** provides advanced algorithms for targeted usage of demand side management by DSOs. The algorithms allow for prediction and calculation of effects of demand response in the electric distribution network.

The University of Manchester shapes new research areas in power system state estimation and advanced load profiling with the focus on multidisciplinary research. This can potentially lead to future consultancy or knowledge transfer to industry in the mentioned areas.

#### DERlab members in NOBEL Grid:











The University of Manchester

# nso LPt



#### Lola Alacreu

Coordinator of NOBEL GRID (ETRA Investigación y Desarrollo)

"The H2020 NOBEL GRID project, with a budget of €14M and 21 institutions from 11 countries, led by the company ETRA, is developing new tools and business models that will allow all European citizens to benefit from more secure and stable distribution networks, promoting the integration of distributed renewable energy sources and increasing the active participation of consumers and final "prosumers" in the energy market. The project began on 1 January 2015 and is estimated to end in the middle of 2018.

Several ICT solutions are being developed within the project and will be deployed and demonstrated in real conditions at five European pilot sites. These solutions will provide benefits to all the actors of the market energy by means of a more sustainable, affordable and secure smart grid.

All solutions designed, developed and demonstrated in the NOBEL GRID project, seek to promote and encourage new models of distribution networks to contribute to a more competitive and efficient electricity market, at the same time helping to solve serious social problems, such as pollution, dependence on fossil fuels and energy poverty. In addition, the project aims to open new markets in the field of smart grids and smart meters, incentivising and promoting the competitiveness of the European industry.

The main role of DERIab in NOBEL GRID is to support the sustainable integration of RES in smart grids by means of standards and common procedures concerning connection, safety, operation and communication of DER components and systems. DERIab strives to reduce standardisation barriers of DER components that will be accepted throughout Europe and the world. The results of the project and afterwards the output of the network will be a significant contribution to the European standardisation activities and will contribute to the harmonisation of the different national standards.

The NOBEL GRID project encourages collaboration and liaisons with other projects or networks. Information regarding smart grid component testing methodology was exchanged between the NOBEL GRID and ERIGrid projects. NOBEL GRID also cooperates with other EU-funded projects by means of the BRIDGE working groups created by the European Commission Smart Grids and Storage H2020 project partners. For example, as an ETRA representative I am the co-Chair of the Business Models Working Group of BRIDGE."

### Impact

Dr. Jan Ringelstein, member of the DERlab project team:

"In my view, the NOBEL GRID project aims at creating a flexible smart grid with downloadable functionality for the end customer's extended smart meter. Imagine, you've just bought a new electric car and would like to know how it performs in terms of energy efficiency, analyse how you can save money and reduce your carbon emission footprint. Imagine, you could download apps onto your smart meter and smart phone that do that for you, using your local infrastructure as effectively as possible. Or say, you want your air conditioning to cool down your house when your community neighbours have excess PV power - you download an app. 'Smart grid downloaded', so to say.



In NOBEL GRID we are developing the infrastructure to allow this - from the customer up to the enterprise level. That means we're empowering the whole value chain with technology for using active customer participation for effective generation, storage and load management beneficial to the whole energy system. We include grid operators, energy service companies, renewable cooperatives and retailers as stakeholders. We want to create building blocks for enabling customers to actively work with energy in their social community instead of just passively using it. We do that to save CO2 emissions, enhance integration of renewables, improve security of supply and increase energy efficiency. This is my NOBEL GRID vision."

# prosumers

In the project, the DERlab Office is in charge of several laboratory testing tasks, validating the technical components. In particular, validation of the extended smart meter and the G3M framework is led by DERlab in different work packages. Further main tasks of the DERlab Office are system integration testing, contributing to the SMX functions by deploying OGEMA, and analysis of and reporting on related standardisation activities.

In addition, DERlab is leading the task of energy policies and regulatory frameworks analysis as well as standardisation activities in the scope of NOBEL GRID topics. DERlab has already published an analysis report on European/national regulations and policies in the fields of smart meters rollout, data access, security and privacy, energy management, demand response, energy market, technical codes for distribution grid, consumer protection and smart cities. This report will be updated at the end of the project in regards to new policies and regulatory frameworks. DERlab, together with NOBEL GRID partners, aims to outline a standardisation map during the project's runtime in order to analyse and exploit the variety of available data models and standards for smart grid data processing components.



Mohamed Shalaby (DERlab) presenting NOBEL GRID poster at IRES 2016



### **Reinforcing Blackstart Capabilities in NETZ:KRAFT**

NETZ:KRAFT: Grid restoration in consideration of future power plant structures (Netzwiederaufbau unter Berücksichtigung zukünftiger Kraftwerkstrukturen) Duration: January 2015 – June 2018 Funding: Federal Ministry for Economic Affairs and Energy (BMWi) Partners: 20 partners, including DERlab Office

#### www.netz-kraft-projekt.de

DERlab members in the project:

 The NETZ:KRAFT project analyses the possibilities offered by distributed and renewable energy resources to contribute to the restoration of the power system after blackouts. Therefore the project combines two different approaches: the top-down approach (re-energising the system from the transmission grid to the distribution grid) and the bottom-up approach (creation of re-energised or still operating islands in the distribution grid which are then synchronised to re-energise the transmission grid).

For the currently commonly used top-down approach, NETZ:KRAFT aims to find new roles for the increasing share of DER in the grid to reliably support the restoration procedures and offer black start possibilities. For the bottom-up approach, the project offers to develop completely new ways in the restoration process.

Involving a large number of case studies and demonstrations, NETZ:KRAFT aspires to set up a framework where, depending on the situation, either the top-down or the bottom-up approach leads to a more stable restoration procedure.



SysTec of Fraunhofer IWES



22 June 2017, in Dresden (DE)



In NETZ:KRAFT, DERlab provides an overview on existing standards regarding grid restoration in different European countries. Taking into account the NETZ:KRAFT results from demos and field tests, recommendations for necessary adaptions on the regulatory framework will be one of the outcomes of the project. The comparison of grid codes of different countries with the regulatory situation in Germany will allow to extend these conclusions to a European level. NETZ:KRAFT investigates the capabilities of DER to contribute to grid restoration after blackouts. Therefore, several case studies and demonstrations are being developed within the project. These include, among others:

- Start of a thermal generation unit, supported by a wind park
- Connection of long overhead lines with wind park available for supply with reactive power
- Connection of load in networks with different generator types (conventional, DER, mixed, etc.)
- Synchronisation of subnetworks
- Grid restoration with HVDC
- Supply islands in distribution networks (case studies: city, rural area, agricultural area and more)
- Analysis of power system protection



Simulation results for island

operation of a microgrid (planned demonstration at SysTec of Fraunhofer IWES): possible duration of island operation depending on the charging status of the battery and time of the blackout occurence. Source: Maria Nuschke, "Development of a Microgrid Controller for Black Start Procedure and Islanding Operation", Proceedings of INDIN17, 24-26 July 2017, © IEEE Industrial Electronics Society



Wolfram Heckmann

Applied Research Project Management (Fraunhofer IWES)

"If we want to pursue Germany's goal of reaching 80% renewable energy by 2050, then we have to consider that grid restoration is prerequisite functionality for renewables. NETZ:KRAFT addresses this very particular aspect – ensuring that grid restoration after a blackout follows without a hitch.

What makes NETZ:KRAFT stand out is that this project is not just about the technology, it also deals with the coordination between system operators. NETZ:KRAFT brings all types of stakeholders - DSOs, TSOs, manufacturers, researchers – to coordinate together for the successful functionality of grid restoration. In this way project results reflect the needs of each system operator as they all are part of the consortium.

And although NETZ:KRAFT is in the first place a national project, DERlab has elevated the project proceedings to the European level. As a result, NETZ:KRAFT outcomes apply to larger frame and will concern stakeholders throughout the continent."






1st NETZ:KRAFT workshop "Grid Restoration in Research Projects - A Workshop for Exchange", June 2016, Kassel (DE)

In the scope of the project, DERlab organised a workshop in June 2016 under the title "Grid Restoration in Research Projects – A Workshop for Exchange". With representatives from other German research projects dealing with related topics on grid restoration and black start, the workshop brought together over 50 experts and enabled insight into similar projects and exchange of ideas.

### Manuela Wunderlich, member of the DERlab project team:

"A large-scale power outage in our electricity grid is a quite undesirable situation – good that this only very rarely happens in Europe. But a failure of the electricity supply for several hours massively impacts all of us: private households as well as industry customers. So we – as actors in the energy supply system – also have to deal with the topic of blackouts: How is the process of restoring a power grid carried out? In case of emergency, which power plants are available for restoration? And how will these procedures develop in the future - when a higher share of renewable and decentralised energy resources is used?

### In NETZ:KRAFT, we are approaching these questions,



focusing on the situation in Germany. Since forever, the emergency plans for restoring the grid follow a top-down strategy: At first, the transmission grid is re-electrified, then the distribution level follows. In this current approach, only very few renewable energy sources are actively involved, although they could offer a set of functionalities to contribute or even accelerate and improve the restoration process. NETZ:KRAFT investigates such possible options through various case studies, for example, through studying how a wind park can support frequency stability.

Apart from support, decentralised energy resources could also offer a completely new possibility: the bottom-up grid restoration. Starting with autonomous supply islands, the grid is restored from the distribution to the transmission level. NETZ:KRAFT is testing in simulations and field tests for which configurations the bottom-up grid restoration can be an appropriate approach.

The overall aim is to bring back the electricity to the customers as fast and stable as possible: So maybe in some cases, the light in our houses can come back faster when decentralised generation opens up supply islands in the distribution grid instead of letting us wait for the electrification from the upper transmission level.

Also with a high share of renewable generation, in our future we might not fear regular blackouts – but our grid operators should be prepared for any emergency cases. In ensuring this also for our future networks, NETZ:KRAFT is pioneering in this topic."

### **ETP Smart Grids Completing First Chapter of Technology Platforms**



SmartGrids-ETPS-III: Secretariat of the European Technology Platform for Electricity Networks of the Future Duration<sup>-</sup> October 2012 – June 2016 Funding: the Seventh Framework

Programme of the EC

### www.smartgrids.eu



are represented in the ETP SG booklet "National and Regional Smart Grids Initiatives in Europe"

The European Technology Platform on SmartGrids (ETP SG) united a large range of stakeholders in the smart grids field in Europe. As such a group, the ETP SG expressed opinion and gave statements regarding the research landscape as well as the developments of smart grids related topics in industry. Therefore, the ETP SG developed a view into the future of smart grids, identifying a path to address current needs and gaps. In this regard, it also acted as a tool to implement the integrated SET-Plan.

The expertise of the ETP SG stakeholders enabled the platform to soundly answer to consultations requested by the European Commission and to influence the Horizon2020 work programmes and thus point out the direction of future research activities.

Between 2014 and 2016, the platform answered consultations on five different topics:

- Barriers to innovation
- Security of supply
- Future market design
- SET-Plan Issue Paper 4 on increasing the resilience, security, and smartness of the energy system
- SET-Plan Issue Paper 7 on becoming competitive in the global battery sector to drive e-mobility forward

The topics were communicated to the platform in form of questions, questionnaires or requests for comments on EC documents. The ETP developed its statements by collecting opinions of the Steering Committee members and consolidating those views in a dedicated document. The organisational work of this process was strongly supported by the ETP Secretariat.

Among others, two of the above mentioned consolidation topics formed a major part of a published report in 2015, which presented the ETP's view on research, development and demonstration needs in the Horizon 2020 Work Programme 2016-2017. One of those topics was "Market Design" ensuring that the development of business cases and tariff structures is included in future research plans. Also identified as a crucial element in the report was the section "Barriers" to Innovation" giving advice on which regulatory challenges must be addressed to drive smart grids technology evolution. Both issues are of key interest in the European smart grids landscape.

The ETP SG's vision was mainly made visible in the Strategic Research Agendas (SRA) - the platform's major document, first version of which was published in 2007 and the updated one "SRA 2035" in 2012. In 2016 ETP SG published three strategy papers:

- "The Digital Energy System 4.0"
- "Progress and Challenges on Asset Management for Future Smart Grids"
- "The need for a fundamental review of electricity networks reliability standards"

Another enhancement of the ETP SG is its role as the contact point for national smart grid initiatives. Smart grid platforms, associations and other groups acting on national or regional levels established a new cooperation with the ETP as well as among each other. Collecting information on smart grids activities in Europe and contacting experts in many countries resulted in a contact with 19 different groups in 18 countries. This cooperation included collecting information from all initiatives, finding links between initiatives, sharing knowledge and best practices and creating a common identity of smart grids initiatives in Europe. As a highlight of this cooperation, ETP SG organised a workshop for representatives of national and regional smart grids initiatives in Europe" presenting 19 platforms and groups with its main objectives, projects and specifications. This overview (first published in 2016) is a unique compilation of information in this field.

Strengthening the collaboration of ETP SG with national and regional smart grids groups was an important accomplished task in the last two years of the platform's operation.

Since spring 2015, four ETP SG workshops have been organised by the DERlab Office. Invitations were distributed, among others, to DERlab members, which allowed them to participate in the events and contribute to discussions. In this way, DERlab members' expertise influenced outcomes of ETP SG.



6th General Assembly of European Technology Platform on SmartGrids, 9 May 2016, Brussels (BE)

### DERlab members in ETP Smart Grids:

### Secretariat:



#### Steering Committee:







Working Groups:















### **Opening the Road to EV Interoperability**



**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, grant agreement no. 608934

www.cotevos.eu

The interoperability between different electromobility devices is key for making charging and other services available to consumers at opportune prices. The integration of EVs into the (smart) grid requires electromobility solutions compatible with electric network management procedures. In addition, technology interoperability across providers and countries is needed for efficient interactions, so that they can plan their market approach in the best way and contribute consistently to the regulatory framework.

The increased and improved interoperability will push the deployment of EVs in Europe.

The EU-funded project COTEVOS (COncepts, capacities and methods for Testing EV systems and their interOperability within the Smart grids) has developed plans and schemes for the assessment, validation and certification of the interoperability of electromobility systems. The interoperability assessment infrastructure has been conceived from a business standpoint: the testing services have to be profitable.

COTEVOS provides methods and procedures to test, analyse and simulate the impact of EV integration in the power grid, helping to assess and solve potential issues regarding the suitability of the available protocols and standards.

The COTEVOS testing environments allow technology providers to demonstrate that their new products really do fulfil the expected features and to improve their designs at different stages of the development process.

Project deliverables, most of them available at **www.cotevos.eu**, present in detail the path and findings of the developed work, from the state of the art and the identification of needs to the design of the different COTEVOS infrastructures according to a common reference architecture and the multiple interoperability procedures and tests carried out by the partners.







Background photo: DTU

The last COTEVOS deliverable - the **White Book "Business Opportunities for Interoperability Assessment of EV Integration"** – describes the whole way and vision from the needs to the strategic approach.

During the project, a number of test cases have been defined and collected in an attempt to cover the full spectrum of interoperability combinations. The test cases have been mapped, condensed and categorised into seven groups: EV Charging and Operation, EVSE Operation, EV/EVSE User Services, EMSP-EVSEO Services, Adaptive Charging, V2X and Grid Services, and Wireless Charging.

COTEVOS ensured interaction and information exchange with major stakeholders, which placed the project in the focus of EV integration in the international smart grid community. Around 400 actors (mainly OEMs, DSOs, electromobility service providers, charging station operators, laboratories and R&D stakeholders) have been regularly invited to participate in the workshops, the COTEVOS Industry Summit and the Interoperability Plugtest<sup>™</sup> on 30 November – 4 December 2015 in Ispra (IT), supported by JRC and ETSI CTI. 262 tests were scheduled and executed at the Plugtest<sup>™</sup>. 215 of the tests had a pass rate, which results in a success rate of 82.1% - a high figure that could be attributed to the maturity of base specifications.

DERIab coordinated the activities around the exploitation of interoperability assessment services, according to EU priorities and market expectations. Market and business rules will determine the legal, economic and technical aspects for the best collaboration among laboratories. Now the coordinated services offer is based on COTEVOS members laboratories (AIT, DTU, IWES, RSE, TECNALIA, TNO and TU Lodz) that developed their infrastructures with the valuable support of the other



project partners (ALTRA-IVECO, ETREL and ZSDistribution, as well as DERIab itself) and the expertise of IDIADA or TU of Dortmund, among others.

Contribution by Eduardo Zabala COTEVOS Coordinator, TECNALIA

### DERlab members in COTEVOS:















### **SIRFN: Leading Global Smart Grids Infrastructure**



The Smart Grid International Research Facility Network (SIRFN) - Annex 5 of ISGAN - gives the participating countries the ability to evaluate precompetitive technologies and systems approaches in a wide range of smart grids implementation use cases and geographies using common testing procedures. Research within each individual member country derives the value of the unique capabilities and environments of the other partner nations. Data from these tests is made publicly available to the smart grids community to accelerate the development of smart grids technologies and systems, and enabling policies.

### www.sirfn.net



October 2016, Niagara Falls (CA)

The International Energy Agency (IEA) Implementing Agreement for a Co-operative Programme on Smart Grids (also known as International Smart Grid Action Network - ISGAN) creates a mechanism for multilateral government-to-government collaboration to advance the development and deployment of smarter electric grid technologies, practices, and systems. It aims to improve the understanding of smart grid technologies, practices, and systems and to promote adoption of related enabling government policies.

The Clean Energy Ministerial meeting of 2010 led to the creation of ISGAN, which was later formally established as an Implementing Agreement under the IEA framework in 2011. ISGAN itself fulfils a key recommendation in the Smart Grids Technology Action Plan released by the Major Economies Forum Global Partnership in 2009. The US proposed the Smart Grid International Research Facility Network -SIRFN - as an ISGAN Annex and led the original development task by working with ISGAN Participants, APEC Smart Grids Test Beds Network, representatives from the DERlab Association and other stakeholders. This effort aimed to develop the concept and identify interested participants among more than two dozen countries which had signed the ISGAN Implementing Agreement or had been invited to participate.

The most ambitious part of the effort was creating the fully functional vision of SIRFN as an organisation able to review, accept, and assign research or testing requests from potential users to SIRFN participants. It was also meant to provide a means of sharing non-proprietary results within the SIRFN network and the broader smart grid research community. Another task foreseen for SIRFN is identifying gaps in test bed capabilities that can be addressed cooperatively in order to both enhance capacity and minimise duplication.



SIREN areas of collaboration



Octobber 2016, Niagara Falls (CA)

Each subtask or technical topic in SIRFN identifies areas of cooperative research or other engagement. Researchers active in each subtask organise workshops, webinars, online dissemination, technical papers and conference presentations.

The initial five-year term of ISGAN as an implementing agreement came to an end in early 2017, but ISGAN activities will continue in its second term. From the very beginning DERIab has been strongly supporting the development of the SIRFN structure as well as the definition of its objectives. As the Operating Agent (OA) of SIRFN, DERlab has been taking an active part in ISGAN activities and events and will continue so in its role as the SIRFN OA during the second ISGAN term.

SIRFN maintains a flexible portfolio based on the participants' interests. For the first five years, it focused on collaborative work in four key areas: test protocols for advanced interoperability functions of DER, smart grid modelling and simulation, advanced laboratory testing methods and power systems testing. In the beginning of the second term, SIRFN will consider additional topics and will set research topics for the term ahead.

Previous experience reveals that power components testing is not enough to ensure system reliability and security. A component that successfully passes a lab test might not behave as expected when integrated with other technologies in a real grid. As automated actions gain importance in grid systems, the interactions among control strategies must be understood. Failure in components and grids have already been reported in these increasingly complex, interdependent systems. To address this, systems-level testing is needed. Under the leadership of Fraunhofer IWES, SIRFN participants are working together to define the appropriate laboratory infrastructure and testing requirements for a systemlevel testing approach. The approach entails identifying a set of relevant use cases, specifying the corresponding testing needs and then mapping these to the state-of-the-art testing capabilities and infrastructure.

### **Countries represented in SIRFN** by **DERlab** members















### **DERlab network in SIRFN**

From the previous experience of the DERlab testing laboratories, several examples have been identified pertaining to why components testing is insufficient to ensure the reliability and security of overall grid operations when such components are connected to grid systems. The objective of this subtask is to identify the best practices of laboratory testing for systems and components in a system context, to define future testing requirements for systems and to describe appropriate laboratory infrastructure. The outcome should be a common view on future testing needs in power systems and guidelines for future laboratory developments.

With the aim to identify how power system testing can help define these testing procedures, SIRFN and its Operating Agent DERlab organised joint workshops on power system testing as side events at the DERlab General Assemblies: in Brno (CZ) on 17 March 2016 and in Arnhem (NL) on 21 March 2017. Workshop participants discussed how power system testing and the use cases considered can contribute to solving the problems of complex grid operation and the changing roles of actors.

DERIab also organised a joint SIRFN/ELECTRA workshop in October 2016 as a side event at IRED in Niagara Falls (CA). Over 30 smart grid specialists took part in the workshop "Testing and Research Infrastructure for Future Power Grids" where they discussed requirements for future RI development. The presentations gave an overview of the current RI involved in ELECTRA and SIRFN activities. The discussions addressed the RI needs for solving specific issues related to future decentralised grid controls, future power system testing, grid flexibility and advanced DER interoperability.

By acting as the Operating Agent of SIRFN, DERlab has strengthened the international collaboration between DERlab members, ELECTRA IRP partners and SIRFN participants.



SIRFN workshop "Power System Testing" at DERIab General Assembly, 21 March 2017, Arnhem (NL)

### DERIab and SIRFN Members Sandia and AIT Teaming up on Automating Smart Inverter Testing Using HIL

With the rapidly changing landscape of grid codes and interconnection standards, manufacturers of DER components are under increasing pressure to reliably update and validate the interoperability and performance of their equipment for different regional requirements and grid conditions.







Photos: Sandia National Laboratories

The Austrian Institute of Technology (AIT) and Sandia National Laboratories have teamed up to introduce a new approach for rapid and concurrent development of controls and application software using a CHIL testbed integrated with an automated testing platform. This approach is expected to help equipment vendors meet evolving grid standards by systematically validating DER performance.

This methodology provides key benefits over traditional power laboratory testing:

- Validating smart inverter grid support functions without expensive power laboratory equipment, but instead, using benchtop equipment
- Executing certification tests to verify controller operation prior to hardware integration
- Allowing quick design iterations of the communication system to provide interoperability to a range of equipment and standards

The novel CHIL methodology, called Smart Inverter CHIL (Si-CHIL), combines the System Validation Platform, developed as a partnership between SunSpec Alliance and Sandia, with the AIT Smart Grid Converter, a universal DER converter platform for R&D applications. The Si-CHIL methodology has successfully been demonstrated at AIT and Sandia for active power curtailment, fixed power factor, volt-var, frequency-watt, and reactive power control.



### **ELECTRA IRP Introducing Web of Cell Concept**



ELECTRA IRP: European Liaison on Electricity Committed Towards longterm Research Activity Integrated Research Programme Duration: December 2013 – November 2017 Funding: FP7-ENERGY Partners: 21 partners, including DERlab

www.electrairp.eu

Researchers involved in ELECTRA REX, October 2016 at TECNALIA, Bilbao (ES)

The validation and testing of future frequency and voltage control algorithms is an essential effort towards the integration of novel control developments into future power systems. The objective of ELECTRA IRP during 2016 and 2017 is to conduct experimental testing for proof of concept evaluation of the developed controllable flexibility solutions for voltage and frequency control.

The evaluation incorporates system modelling and simulation tools to prove the system performance across numerous devices distributed in the power system at laboratory scale. In order to facilitate the integration of the controllers into a laboratory environment, SGAM has been selected as a tool to help transition from the development of controllers to their evaluation and testing. ELECTRA IRP has developed a three stage methodology utilising SGAM for the purpose of formally determining an experimental plan and KPIs. The three stages of the methodology are:

- Consolidated functional descriptions
- Laboratory implementation descriptions
- Experimentation descriptions and KPIs



Prof. Graeme Burt presenting ELECTRA REX at DERIab General Assembly, 18 March, 2016, Brno (CZ)



### DERlab members in ELECTRA IRP:



























### Helfried Brunner

Technical Coordinator of ELECTRA IRP (AIT - Austrian Institute of Technology)

"The European Integrated Research Program on Smart Grids ELECTRA is approaching its final year. It promotes new radical control solutions for the 2030+ power system real-time operation, utilising flexibility from across traditional boundaries (e.g., voltage level, stakeholders). Important progress has been made in the definition of the Web-of-Cells (WoC), which is a decentralised real-time control concept where the power system is divided into small cells and where the need for reserves activations as well as the activations themselves are dealt with in a decentralised manner by cell system operators. Thus, the concept is following the paradigm of solving local problems locally. It is focusing on local inter-cell tie-line power flow deviations – comparable to the well-known Area Control Error, but on a cell level – rather than system frequency, where the responsibility for detecting and correcting such real-time deviations is delegated to local operators. Obviously, local voltage problems will become more important as well, and it must be dealt with by the local operator anyway.

In the previous period, the project translated the WoC related highlevel concepts into more detailed conceptual solutions and selected the specific use case variants to be further developed, simulated and then validated experimentally in different research facilities by ELECTRA partners during the fourth and final project period. In order to face the challenges of the future, the implementation of new technologies and solutions into a highly reliable and secure power system is like an operation on the open heart. For that reason validation and verification of new concepts like the ELECTRA Web-of-Cell on simulation and lab-scale level is crucial for reducing uncertainties before integrating them into the real system. Hence, research infrastructures and related approaches for power system testing to be further developed by the DERlab partners are crucial for the transition of the energy system in the upcoming decades."

### **Global Smart Grids Infrastructure at a Glance**

### in **DER**lab Database





Maintained by DERlab since 2012, the DERlab Database of DER and Smart Grid Research Infrastructure openly provides coordinated information on smart grid and DER laboratories, testing facilities and similar competencies.

### infrastructure.der-lab.net

Be it for ensuring the reliability of the existing equipment, for further development of equipment functionalities or for testing new methodologies in research projects - researchers and developers in the smart grid and DER field need laboratories and testing facilities for experiments, demonstration pilots and other research purposes.

### In order to connect existing labs with researchers and potential customers, DERlab offers a unique service - the DERlab Database of DER and Smart Grid **Research Infrastructure.**

In September 2016, DERlab released the database version 2.0, with new extensive functionalities. Currently, the directory provides information on over 50 institutes over the world, presenting more than 200 labs, testing capabilities and services. Each institute has the chance to present extensive information about their facilities for potential customers, such as:

- Static and mobile equipment
- Power range
- Simulation and optimisation tools
- Offered testing services within the laboratory
- Quality management and standards compliance of the offered testing services

### Examples of research infrastructures listed in the database cover a broad range from PV system labs, PHIL simulation environments or microgrid configurations.

The database is strongly supported by the ISGAN Annex 5 SIRFN and the EU-funded projects ELECTRA IRP, ERIGrid, COTEVOS, SOPHIA.

- Simulation/optimisation tools:
- DIgSILENT Power Factory: grid simulation, voltage control
- · Matlab (MatPower and other tools): load flow analysis and control systems, energy management tools, state estimator

#### Standards compliance:

- CIM: data models and communication layer
- IEEE 61850: DER representation, communication protocol definition and test (only for part of the test facility)
- Modbus TCPIP: communication with instrumentations and components
- CAN 2.0 part B and CANOpen: communication with battery BMS

Quality management/testing protocols: Laboratories are certified according to ISO9001:2008.

#### Testing services:

- Development, optimisation and testing of smart grid operation and control algorithms · On grid and off grid (islanded) AC microgrid testing
- DC microgrd testing (including management and control algorithms)
- Characterisation and testing of generators and storage systems
- Innovative instrumentation and component testing
- · AC/DC converters testing grid connected and in island operation
- · Management of EV charching station: testing of charging control and management algorithms
- · Domotical house management: testing of management and control strategies

### Ricerca sul Sistema Energetico S.p.A. (RSE)

Country: Italy



Facilities: DG Test Facility



Description: RSE carries out research into the field of electrical energy with special focus on national strategic

RSE

projects funded through the Fund for Research into Electrical Systems. It is an entirely publicly owned joint

Description: It consists of a LV microgrid, connected to the MV grid by means of a 800 kVA transformer. It is constituted by several generators with different technologies (renewable and conventional). controllable loads and storage systems. DER-TF can provide electricity to the main grid with a maximum power of 350 kW.

- + Static Equipment
- + Mobile Equipment

#### Distributed Energy Resources Test Facility - Electric Vehicles research

Description: RSE activities in the field of Electric Vehicles have a multidisciplinary approach and aim at evaluating the effects of electric mobility on the whole power system, addressing regulatory aspects

#### National Technical University of Athens – Institute of Communication and Computer Systems (NTUA-ICCS)



Country: Greece Website Website Smart RUE

Description: The Institute of Communication and Computer Systems (ICCS) is a private law body associated with the Department of Electrical and Computer Engineering of the National Technical University of Athens (NTUA). ICCS has been established in 1989, in order to carry research and development activities in the fields of telecommunication systems and computer systems and their applications in a variety of applications, such as electric power systems, software and hardware engineering, control systems and biomedical engineering. The Electric Energy Systems Laboratory (EESL) is one of the Research Groups of ICCS and offers various degrees of experimental training for students, as part of relevant courses. NTUA has participated in more than 40 research projects, most of which are collaborative EU funded projects (...)

For more technical specifications and larger images, see here (PDF,

+	Facilities
+	Simulation and Optimisation Tools
+	Standards Compliance
+	Quality Management
+	Testing Services

SCADA Technologies and security/privacy regulations

### **RESEARCH INFRASTRUCTURE**

DIRECTORY	VIEW ALL LISTINGS		
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- AC/DC converters testing grid connected and in island operation
- Management of EV charching station: testing of charging control and management algorithms
- Domotical house management: testing of management and control strategies

REACH YOUR CUSTOMERS: MAKE ENTRY IN DERLAB DATABASE FREE OF CHARGE

In order to provide an up-to-date overview on the existing research infrastructures all over the world, DERIab strives to expand the database on an ongoing basis, encouraging all institutes active in the field of DER and smart grids to submit information on their facilities. DERIab offers this service of including your facilities in the database free of charge at

infrastructure.der-lab.net/add-your-ri-database:



The database is utilised by the broad international network of DERIab - your targeted customers

You ensure exposure in the DER and smart grids community as DERIab actively promotes the database through its large network, reaching smart grid stakeholders all over Europe and the US

Your targeted customers can easily find specific services offered by your facility - thanks to the enhanced database functionalities

By providing your entry in the database, you and DERlab support the common goal of the smart grids and DER community - to assist researchers in their access to laboratories and to contribute to the future with prevailing share of renewable energy

# Improving Grid Stability with DER Support in DEA-Stabil

DEA-Stabil investigated the role of wind generators and PV to support grid stability in distribution networks. The results of the project were used to draw conclusions and develop recommendations in various fields:

- Recommendations for future regulations, grid codes and standards
- Recommendations for future research activities in related fields

DEA-Stabil considered the currently existing regulations in order to develop recommendations from the project's demonstration results and ensure their validity across different countries. For this purpose, the DERlab Office deployed the database "Generator to Grid Database – Grid Connection Requirements for Generators". Within DEA-Stabil, DERlab transferred its content into the newly launched "Generator to Grid Wiki" extending the number of entries, updating information, and adding features. The wiki is publicly available at **wiki.dergridrequirements.net**.

The results and recommendations of DEA-Stabil were disseminated in the final workshop on 13 October 2016 in Kassel (DE) with participants from the project consortium as well as national industry and grid operator representatives. The demonstrator, built at SysTec Test Center of Fraunhofer IWES within the project, was deployed in the live demonstration of the system studies. In 2017 DERlab released all results and recommendations in a final report available at **der-lab.net**.

### **DERlab network in DEA Stabil**

DERlab

The DERlab network brings the topics and results of DEA-Stabil into the European dimension. As the project was funded by the German government, the first aim of DEA-Stabil was to draw conclusions on grid stability for the German network. DERlab expanded this scope in fostering knowledge exchange within its network as well as with other European bodies and globally with SIRFN. Furthermore, the involvement of DERlab and its knowledge on European grid requirements and standards allowed an extrapolation of the results to the European level. DERlab elaborated the projects recommendations, giving advice on how future research and regulatory framework could be adapted in view of grid stability support services.

Fraunhofer IWES was directly involved in DEA-Stabil, performing proof of concepts of new control strategies. All laboratory studies were carried out in the SysTec laboratory of Fraunhofer IWES, offering all necessary equipment and simulation capacities. More specifically, Fraunhofer IWES carried out the following practical tasks in DEA-Stabil:

- 1. System stability studies in inverter-dominated grids
- 2. Model development of inverter-based generation units
- 3. Development of new control strategies in inverter-dominated grids
- 4. Implementation of new inverter controls in prototypes

**DEA-Stabil**: Examination and improvement of methods for maintaining grid stabillity while increasing the supply of decentralised renewable energy sources (Beitrag der Windenergie und Photovoltaik im Verteilungsnetz zur Stabilität des deutschen Verbundnetzes "DEA-Stabil")

### Duration:

April 2013 – September 2016 **Funding**: Federal Ministry for Economic Affairs and Energy (BMWi: Bundesministerium für Wirtschaft und Energie)



PHIL testbench at SysTec of Fraunhofer IWES



### **Digest of Main Results**

DEA-Stabil aimed to investigate the stability of the grid with control methods provided by DER. Types of stability studies carried out in the project and exemplary results and main conclusions are presented below. For most of the following investigations, the IEEE 39 bus system was used as an underlying network model. According to a study performed within the project, the IEEE 39 bus system represents the German electricity grid well enough in order to draw qualitative conclusions for the real network. The original IEEE 39 bus system was adapted to the needs of DEA-Stabil in replacing synchronous generators partly by DER. Most studies were performed at a share of 50% DER.

### **Voltage Stability**

The impact of three functionalities of inverter-based generators on the voltage stability in case of a three-phase short circuit was investigated: FRT capability, fast reactive current injection, and active power recovery rate. In all following figures showing voltage curves grey lines represent the use of generators without the considered functionality.

FRT capability: Without FRT capability the loss of generation is not compensated for cases with high share of inverter-based generation, leading to a voltage collapse. In contrast, FRT capable units can secure voltage stability. An important finding
 also from an economical point of view – is that the short-term voltage stability can also be improved significantly if only part of the distributed generators are equipped with this functionality.



• Fast reactive current injection during the fault also shows a positive impact as the voltage recovers faster than in the case of inverters without respective control functions (this is valid for investigated transmission grid; generalisation for distribution grids cannot yet be drawn)

Active Power Recovery Rate: In German Grid Codes a relatively slow active power recovery rate is allowed compared to other European countries. A comparison between fast (coloured lines: 80% of nominal capacity per 0.2 seconds) and slow (grey lines: 80% of nominal capacity per 1 second) active power recovery shows that a low rate – as currently implemented in the German system – can harm the system stability. Therefore, a higher rate is recommended as a result of these investigations.



### **Frequency Stability**

In the IEEE 39 Bus System two simulation cases were considered in order to test the impact of control methods for wind turbines on frequency stability: load shedding and switch-off of a generator. For both cases, generators with proportional primary control and with df/dt control were compared with wind turbines without these functionalities as well as with the original system configuration with synchronous generators instead of wind turbines.

In both simulation cases, proportional primary control (green line) was capable to reduce the frequency deviations significantly compared to both wind turbines without control (blue) as well as to the original system (orange):



of load 24 with 50% penetration of wind turbines, measured at generator G01

In contrast to this, df/dt control (green) could not improve the behavior compared to the original system with synchronous generators. In case of load shedding the improvements compared to wind turbines without control functionalities were minimal. For the generator switch-off, the df/dt control showed a clear improvement with the control function, although the behavior of the original system was not reached.



### **Rotor Angle Stability**

In order to secure the rotor angle stability, the impacts of dynamic breaking was studied. The breaking resistor functionality of traditional dynamic breaking was emulated by switching off inverter-based generation in the instance of fault clearance and then restarting it after a defined brake time. Consequently, the load for the generators is heightened just as the traditional braking resistors do. The figure below shows the resulting critical clearance time (CCT) for the case with (red) and without (blue) dynamic breaking. In the investigated case, the introduction of dynamic breaking could increase the transient rotor angle stability in terms of a higher CCT – but only for high DER penetration rates.



Influence of dynamic braking on critical clearing times

### **PHIL Testing**

For the stability investigations in the framework of the project, the conception and setup of a demonstrator at SysTec of Fraunhofer IWES was an essential part. Therefore, a PHIL system – consisting of a Virtual Simulated System (VSS) and a Physical Power System (PPS) – was chosen and set up. The studies were carried out using the IEEE 9 Bus System. The initial studies on grid stability could therefore be applied to a specific case and could be verified. A developed wind park control, serving to provide synthetic inertia, was successfully implemented on an inverter and tested in a network simulation. Exemplary results are presented in the figures below. Among others, the result of a fast active power recovery leading to a more stable network could be also shown in the PHIL system. Furthermore, the current contribution of inverters on grid stability was tested and optimised via different parameters in a grid simulation with a high share of DER.





Exemplary results of testing electronic inertia control

### Recommendations

The continuous increase of penetration rates of inverter-based generation to the grid has further enhanced its complexity. This addition of the new generation along with a large number of competitors and with the liberalisation of the electricity market has led to new challenges for proper planning and operation of the present and future power systems: increased level of complexity, stochastic nature of power transfer capabilities, and bidirectional power flow across the system.

In order to successfully manage the transition towards a more sustainable power system, the technical rules applied to all kinds of generation must be still suitable in years and decades from now. The challenge is to estimate today which technical features will be crucial for the stable operation of the power systems, in light of a generation mix that changes from centralised, relatively large power plants using synchronous generators connected to the transmission grid, towards a decentralised, mainly inverter-based generation mix that uses volatile renewable sources.

In this context, the activities of the DEA-Stabil project concentrated on analysing the influence of growing shares of inverter-based generation on the transmission system stability. For this purpose a large number of investigations on transmission system test benchmarks integrating high shares of inverter-based generation have been performed while considering the current performance requirements listed by the current grid codes.



Power System Stability

(Source: EEE/CIGRE Joint Task Force on Stability Terms and Definitions, 2004)

### **Regulatory Framework - Network Code Development**

The grid integration of inverter-based generation and stringent requirements by the sensitive loads have raised serious concerns related to the security, reliability, and stability of the power supply. To safeguard the electric power systems against failures and address the issues raised, rules and regulations are required. Grid codes are the key factor for the technical performance of any new installed generating plant.

In this light, the power system stability investigations performed within the DEA-Stabil research activities have concluded that appropriate system studies are needed as basis for formulating requirements for grid integration of inverter-based generation. These requirements have to already consider the mid-term targeted shares of inverter-based generation, their provisional regional distribution and capacity and should be developed considering the potential of new technologies.

Furthermore, the studies have shown that the impact resulting from large-scale integration of inverter-based generation in the electrical grid has to be understood in the framework of DSO-TSO interaction for effective provision of grid support services at all voltage levels. The collaboration between system operators from both transmission and distribution levels is critical in the process of grid code requirements definition.

More specifically, one part of the voltage stability investigations has shown that the rate of active power recovery is an aspect to be considered in dynamic studies and should be modelled. The conducted studies compared current grid code requirements in terms of active power recovery rates, with possible stronger requirements. It has been concluded that the current requirements could be more demanding in terms of how fast the recovery of the active power should be achieved, as this capability has a very strong impact on the power system stability in case of voltage disturbances.

Frequency stability investigations have shown that inverter-based generation is capable, with the support of appropriate control strategies, to provide very fast frequency support. As more inverter-based generators are being installed in existing grids, more conventional generation units may be displaced leading to unprecedented rapid changes to the power systems. In this context fast frequency support functions are one of the critical aspects to be urgently addressed by grid codes in order to allow the grid to safely accommodate high shares of such generation.

### Recommendations

#### General

Appropriate system studies should represent the basis for formulating requirements for grid integration of inverter-based generation and should consider:

- appropriate shares of inverter-based generators
- requirements for the regional distribution and capacity of the generation

Requirements should be developed under consideration of the new technologies' potential.

The collaboration among the system operators from both transmission and distribution levels is critical in the process of requirements definition. There is a need for coordination between transmission and distribution for effective provision of services at all voltage levels.

### Specific

- Active power recovery rates requirements should specify clearly a minimum of expected technical capabilities for inverter-based generation
- Grid codes should address the topic of very fast frequency response

### **Future Research**

Electrical power systems and their control are facing a continuous transformation process. Nowadays, the grid control is mainly based on large-scale power plants with synchronous generators. However, the share of grid-connected inverter-based generators is continuously increasing. In the future grid scenario of up to 100% shares of inverter-based generation, the active contribution of all power sources to the grid stability and to the security of power supply becomes crucial. Therefore, new services are required at the power system level for enabling services like fast Frequency Containment Reserve or provision of synthetic inertia. Current strategies for the control of inverter-based generation are expected to be reconsidered for the future power supply scenarios in order to meet stable network operation conditions in case of fault scenarios, for example, system split or short circuits. Inverters behave currently in accordance with the connection requirements, but whether this contribution to the short-term stability is sufficient after the occurrence of a disturbance in the future power system is uncertain.

The dynamic interaction between the fast controls of distributed generation systems can be problematic, particularly at high penetration levels. Inverter-based generation is connected to all grid voltage levels. Grid connection requirements, which would be appropriate to ensure transmission system stability, do not necessarily have a positive impact on the distribution system level. Similarly, requirements which apply at the distribution level are not necessarily relevant for the transmission level. Therefore, one aspect which urgently needs attention is to determine the relevance of different support services for the different voltage levels, as well as the possible interactions of the different controls on the same and on different voltage levels. Under this rationale, the impact resulting from large-scale integration of inverter-based generation in the distribution grid needs to be understood in the framework of DSO-TSO interaction.

For this purpose, one first important step is the development of appropriate power systems models, inverterbased generation models (e.g., PV, wind, storage) and related controls, as well as complex loads, and dynamic network equivalents.

System support functions and related coordination mechanisms for the contribution of different inverterbased generation technologies to stable and safe future power system operation have to be described and developed. The appropriate and optimised distribution of the different inverter-based generation technologies providing grid support services, to the individual voltage levels, the related controls and the adaption of protection settings and schemes, are all urgent topics to be scientifically addressed.

### Recommendations

Future research should address the security, reliability and stability of inverter-dominated grids, including such activities as:

- Investigation concerning the adaption of currently required system support services options and further development of those, as well as their interaction with the protection schemes and afferent impact on the grid stability
- · Elaboration of a deployment strategy for grid services considering a mix of technologies
- Development of appropriate simulation tools:
  - Test systems models
  - Dynamic loads modelling
  - Dynamic equivalents models
  - New/adapted protection and control settings

## Research Infrastructure Testing and Consulting Services

Photo: Solar PV RTC, Sandia National Laboratories



### **DERlab Research Infrastructure**

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33 Sandia DETL (US)														

Research infrastructures of the member institutes of the DERIab 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, laboratories of DERlab members provide the services of testing individual components and complete systems, and verifying compliance with international and national standards or certification procedures.





National Renewable Energy Laboratory (NREL)



The National Renewable Energy Laboratory (NREL) is the US Department of Energy's (DOE's) primary national laboratory for renewable energy and energy efficiency research. From scientific discovery to accelerating market adoption, NREL deploys its deep technical expertise and unmatched breadth of capabilities to drive the transformation of the nation's energy resources and systems.

For NREL's recent reports, publications, and overview of testing capabilities, please visit:

### infrastructure.der-lab.net/nrel



### Hardware in the loop with external grid simulation for PV

NREL recently completed a first-ofa-kind experiment that connected megawatt-scale PHIL testing with advanced distribution management systems and cutting-edge visualisations to evaluate the effect of large PV systems on distribution circuits. The study performed by NREL, GE Grid Solutions, and Duke Energy found that when a large solar PV system is connected to the electric grid, a centralised control system at the utility can regulate the voltages on the grid's distribution feeder lines better than advanced inverters alone. This research can help utilities understand the impact of high penetrations of PV on distribution system voltage management.



#### Large-scale transmission-distribution simulation

NREL researchers have developed the Integrated Grid Modeling System (IGMS), a first-of-its-kind, large-scale simulation tool specifically designed integrate transmission to and distribution. IGMS is able to capture distributed generation not simply as negative load but as an active participant in large-scale power systems operations. Using high-performance computing, IGMS models hundreds or thousands of distribution systems in co-simulation with power markets and automatic generation control, which keeps the modelled grid in balance with its load. IGMS operates at a massive scale, offering unprecedented resolution from wholesale power markets down to appliances and other end uses.



### **New capabilities**

Since its inception in 2013, the Energy Systems Integration Facility (ESIF) of NREL has had a PHIL capability, which allows actual power equipment to be connected to software models, such as a model of an electric grid, to see how they interact. In 2016, ESIF engineers extended that capability by connecting software electric grid models to the ESIF's Smart Home Test Bed, which consists of a PV system and a variety of smart home appliances as well as a home energy management system (HEMS). The electric grid models were executed on the ESIF's supercomputer to simulate hundreds of additional homes with HEMS and evaluate the system-wide impacts of smart homes. The work involved adding electrical connections and communications interfaces between the smart home devices and advanced simulations.

In 2017, NREL plans to extend integrated transmission and distribution system modelina with added ability to co-simulate communications systems. As part of the Grid Modernisation Laboratory Consortium, NREL has been working with other US National Laboratories to develop the Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS) framework that integrates a variety of grid and communications modeling tools to better represent how the grid can operate with large amounts of distributed resources and communications interdependencies.



#### **Services**

NREL provides a wide range of research services in energy systems integration in the ESIF and National Wind Technology Center (NWTC). NREL research in grid modernisation includes the following technical areas:

- Integrated devices and systems
- Sensing, measurement, forecasting
- Power systems operations and controls
- Power systems design and studies
- Security and resilience
- Institutional support



#### Partnerships

During 2016, NREL had over 80 partners on a variety of research projects in energy systems integration and grid modernisation. Many of these partnerships were with industry in the power system sector to solve critical challenges with integrating variable renewable energy at the distribution and transmission levels. NREL is also co-leading the Grid Modernisation Laboratory Consortium (GMLC), which was established as a strategic partnership between DOE and the national laboratories to bring together leading experts, technologies, and resources to collaborate on the goal of modernising the nation's grid.

Photos: Dennis Schroeder, NREL





**DNV GL** provides classification and technical assurance along with software and independent expert advisory services in the fields of onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, and sustainable energy use, as well as energy markets and regulations.

DNV GL enables organisations to advance the safety and sustainability of their business as well as provides certification services to customers across a wide range of industries. One of their facility highlights is the Flex Power Grid Laboratory (FPGLab), which focuses on DER and RES integration for smart grids and power electronics development.

### infrastructure.der-lab.net/dnv-gl



In 2016 DNV GL started development of HVDC circuit breaker test procedures and test-circuits for meshed (offshore) grids within the EU PROMOTioN Project.

Being a partner in the ERIGrid project, DNV GL started research into data analytics applications for power system stability.

### **New capabilities**

In 2016 DNV GL installed an OPAL RT real-time simulator at the Power System and Automation lab for HIL relay testing.

In 2017 the Flex Power Grid Lab plans to add a 1 MW DC source to the existing infrastructure and to develop further power cybernetics test capabilities.

### Services

DNV GL unites the strengths of DNV, KEMA, Garrad Hassan, and GL Renewables Certification. DNV GL's 2,500 energy experts support customers around the globe in delivering a safe, reliable, efficient, and sustainable energy supply. DNV GL delivers world-renowned **testing, certification and advisory services to the energy value chain** including renewables and energy efficiency. Their expertise spans onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, and sustainable energy use, as well as energy markets and regulations. DNV GL's **testing, certification and advisory services are delivered independently from one another.** 









Austrian Institute of Technology (AIT)



The Austrian Institute of Technology (AIT) is Austria's largest research and technology organisation. As a national and international network node at the interface of science and industry, AIT performs contract research, licensing IPR or launches spin-offs for industry partners as well as provides input in the form of coordinating foresight processes, performing studies and evaluations and developing concepts and programmes with regard to infrastructure and technology policy decisions for public institutions.

The main research areas of AIT are energy, mobility systems, lowemission transport, health & bio resources, digital safety & security, vision, automation & control and technology experience, all paired with competence in the area of innovation systems & policy.

infrastructure.der-lab.net/ait



Among AIT's activities in 2016 were:

- Integration of ICT/communication emulation into real-time HIL experiments
- Development of a flexible smart grid converter platform to be used in realtime HIL experiments

### New capabilities

Among AIT's facilities in the field of smart grids is the SmartEST (Smart Electricity Systems and Technology Services) laboratory analysing interactions between components and the grid under realistic conditions. In 2016 the laboratory infrastructure was extended with the commissioning of the following equipment:

- 4 Quadrant Grid emulator (AC source), 800 kVA, 480V, can be operated as power amplifier in a PHIL setup
- Bi-directional DC source/battery emulator, 700 kVA

In 2017 AIT intends to realise a setup for smart and secure secondary substations as an addition to the existing SmartEST low voltage grid laboratory. Advanced secondary substation functionalities are subject to laboratory analysis. The setup should be used to gain experience with secondary substation equipment available today and realisation of nextgeneration functionalities.

AIT also plans to extend its DER validation and testing services to energy storage systems. Therefore, an own energy storage system test bed will be implemented as an addition to the existing SmartEST laboratory.



Photos: SmartEST laboratory of AIT

### Accomplishments

AIT produced a number of publications on a range topics, such as:

- Holistic power distribution system validation and Testing, Emulation of a High Voltage Home Storage Battery System using a Power Hardware-in-the-Loop Approach
- Evaluation of System-Integrated Smart Grid Devices using Software- and Hardware-in-the-Loop, applied Security-by-Design for DER units

For details please visit:

### infrastructure.der-lab.net/ait





### Services

### Smart grid system and DER-oriented expertise and validation/testing:

- Integration of DER, standards, national requirements in EU and USA
- Power Quality (PQ) lab test and field monitoring: impact of DER components including storage on PQ (e.g., harmonics, flicker), impact of PQ disturbances on Distributed Gener-ation (DG) components (e.g., voltage sags, over-voltages)
- Safety of DER components (research and testing): PV inverters (e.g., DC current, Loss of Mains protection) and PV modules
- Quality and performance of DER components including storage and systems: inverters performance (e.g., efficiency, MPPT efficiency, derating), quality and performance control of PV modules, performance assessment of PV systems, online monitoring, mutual interference of multiple DERs in distributed power system
- Qualification testing and conformity assessment of PV and battery inverters and protection devices according to diverse national standards and recommendations
- Energy storage system validation
- EV supply equipment/charging system validation

### Smart grid simulation/HIL-based and automation application development/testing:

- Experimental real-time simulation platform for advanced PHIL and CHIL analysis
- Distributed/coordinated/central voltage control approaches with many distributed generators across a section of network
- Validation of energy management systems and distribution SCADA
- Standard-based controller implementation (e.g., IEC 61850/61499, SunSpec)
- Interoperability and communication testing

### Partnerships

In 2016 Sandia and AIT initiated a joint project to introduce CHIL testing in the SIRFN advanced inverter testing activity. For this purpose, the AIT Smart Grid Converter was deployed at Sandia's Distributed Energy Technology Laboratory (DETL) and is being used as a reference test object to develop and validate new test procedures for the automated testing of advanced grid support features of inverters (see p. 45 for more information on this collaboration).

### **KIT Scaling up PHIL Infrastructures**



Karlsruhe Institute of Technology (KIT)



Karlsruhe Institute of Technology (**KIT**) is a public corporation pursuing the tasks of the Baden-Wuerttemberg state university and of a national research centre of the Helmholtz Association in the areas of research, higher education, and innovation. One key facility of KIT in the area of energy is the smart platform Energy Lab 2.0 which analyses interactions of different components of future energy systems to accelerate the German "Energiewende" (energy transition) and the integration of RES in electricity production.

infrastructure.der-lab.net/kit



At the start of 2016 the PHIL group at the Institute of Technical Physics (ITEP) of KIT completed the setup and commissioning of the 30 kVA PHIL training station. Very soon thereafter first examples of decentral energy generation in a grid have been implemented on the OPAL-RT OP5600 real-time simulator in the HYPERSIM software environment. Open and closed loop PHIL experiments have been conducted. This work made use of scaled transmission grid hardware components which were purposely acquired. Simulations of the hardware in the real-time system as well as in well-established simulation software packages, such as PowerFactory and MATLAB/Simulink, have been compared with real measurements verifvina software and hardware utilities.

Another very important issue of PHIL systems, the interface of the simulation and the hardware, has been dealt with over the last year. These issues are mainly due to latencies which are caused by the power amplifiers and measurement Several known interface devices. algorithms, standard ones, such as the Damping Impedance Matching Method, as well as newly developed ones, such as Wideband System Identification, have been implemented, tested and verified by simulation and on the PHIL system utilising suitable hardware. This provides the PHIL Laboratory at ITEP with the ability to test all sorts of power hardware.

The ITEP PHIL group in collaboration with Competence E of KIT successfully incorporated a PV test station in the 30 kVA PHIL training station in closed loop configuration. During test runs the behavior of the hardware, consisting of a battery and inverter unit, has been examined under different operation and failure conditions. Variations of the energy generation and the household load have been emulated and the external lowvoltage grid has been realised in the realtime simulation unit of the PHIL system. The PV test station unit has been exposed to grid instabilities, such as frequency drifts, voltage sags and glitches as well as shortcuts.

At present the research group addresses a wide range of topics coming from investigations and optimisation of LV grid switchboards to ensure their readiness for future applications to transmission grid simulations including superconducting cables for developing the German grid. These activities also include the aforementioned PV system tests. Other storage applications to stabilise and enhance service capabilities of grids with highly decentral renewable energy generation are as well investigated.



in the 30 kVA PHIL training station

#### **New capabilities**

In 2016 the laboratory was upgraded with:

- A fully functional PHIL 30 kVA training station including an OPAL-RT OP5600 real-time simulator and power amplifiers by Spitzenberger & Spies as well as scaled transmission grid components as optional power hardware for testing
- Two analog measurement systems of micro-second response times adapted to the required measurement range of the PHIL system
- Software licenses for relevant software products, such as OPAL-RT's HYPERSIM and DIgSILENT PowerFactory

For 2017 it is planned to start the construction of the **Smart Energies and System Simulation Control Center** (SEnSSiCC). This building constitutes the core part of the Energy Lab 2.0 infrastructure. It will host a 1 MVA PHIL system as a major Laboratory component next to a microgrid environment, a grid control center and a high performance computing system. Besides the SEnSSiCC Laboratory environment the Energy Lab 2.0 includes amongst other components a 1 MW battery storage unit, a 1 MW (peak) photovoltaic field, a jet-fuel synthesis facility, the biolig® plant and a gas turbine. Hence, when realised the Energy Lab 2.0 infrastructure represents a unique environment in Germany and Europe for studying future power grid applications. For the purpose of timely proceeding, the acquisition of the PHIL system is planned to be completed in early 2018. The setup of the PHIL Laboratory should start at the time of completion of the SEnSSiCC building.

#### Partnerships

### The PHIL groups at ITEP/KIT and the Austrian Institute of Technology (AIT) maintain a partnership and a consultancy relationship with mutual visits and collaborative work in 2017.

The PHIL group at ITEP/KIT already offers the use of its facilities, i.e. especially the 30 kVA PHIL training station, to other members of ITEP, institutes of KIT and the Helmholtz Association of German Research Centers as well as academic and industrial partners. Collaborative work has started and several projects have been announced and are currently in review or under investigation. One of them includes the operation and application optimisation of a flywheel with superconducting bearings.

#### Services

In 2016 the ITEP PHIL group started to offer external companies and other partners the possibility to test and validate their power hardware at the ITEP PHIL Laboratory. Here the focus lies mainly on new technologies.



### Fraunhofer IWES Upgrading Testing Facilities



Fraunhofer IWES



The research activities of the Fraunhofer Institute for Wind Energy and Energy System Technology (Fraunhofer IWES) cover all aspects of wind energy and the integration of renewable energies into energy supply structures.

Fraunhofer IWES carries out specialist research in the areas of energy management and energy system technology, finding solutions for economic and technical problems relating to the energy transition.

> infrastructure.der-lab.net/ fraunhofer\_iwes



In its test centre for smart grids and electromobility SysTec, Fraunhofer IWES is developing and testing new equipment and operation strategies for smart low and medium voltage grids. In addition, investigations regarding grid integration and grid connection of EVs and their power generated from renewable energy sources, as well as photovoltaic systems, wind energy plants, storage and hybrid systems are carried out in SysTec under realistic conditions.

A large open-air ground of ca. 80,000 m<sup>2</sup> offers sufficient space and very good conditions for solar and wind energy. Furthermore, the open-air ground provides configurable distribution grid sectors (low and medium voltage), as well as a route suitable for test inductive charging systems for EVs.

The eastern part of the premises comprises three laboratory divisions. One of the labs includes a testing area for low and medium voltage converters, electrical machines or grid equipment. There it is possible to develop and test the electrical properties and in particular the ancillary services of remote generators in the power range up to 6 MVA. A mobile test container able to be used to measure the FRT of generation plants has been integrated into the laboratory.

The second lab is equipped with facilities to test grid integration of EVs and power storage. In addition to hardware simulators for batteries, bidirectional charging controllers, charging columns and grid simulators, there is a roller chassis dynamometer for EVs to replicate operational profiles as well as a test facility to analyse inductive energy transfer.

The third lab is dedicated to the testing and development of electrical machines.

In 2016 Fraunhofer IWES carried out a range of activities in regards to power system testing and co-simulation:

- A 2.5 MW utility scale PV inverter was tested in the testing lab for grid integration at SysTec regarding the compliance with different grid codes. Tests included static tests (e.g., P/Q capability) and dynamic tests (FRT capability). A modular DC source with a total capacity of up to 3000 A at 1000 V was utilised to perform the tests.
- Several CHP units in the power range of several 100 kW were tested concerning the compliance with grid codes.
- PHIL tests were performed in the frame of the DEA-Stabil project. The tests made use of the real-time power system simulation, multi-terminal dynamic power amplifiers (up to 270 kVA capacity) and experimental power inverters with new grid supporting control functions.

- Several tests were performed to study the behavior of PV inverters during short circuit in the LV grid. The tests aimed to analyse the short-circuit current wave form of inverters and the impact on network protection devices.
- New generator technologies have been developed and tested in the lab for electrical machines at Fraunhofer IWES SysTec in the frame of the "Magnetring" project. The objective is to develop electrical generators with significantly lower weight per power ratio for wind energy applications. The feasibility of the new concept was demonstrated.





 The setup for short circuit testing



### Accomplishments

R. Brandl and T. Degner of Fraunhofer IWES won the Best Poster Award for "Power Hardware in the Loop Studies for Transmission Network Stability Behaviour" at IRED 2016 (7th International Conference on Integration of Renewable and Distributed Energy Resources).

### **New capabilities**

The SysTec laboratory building was extended by a new segment hosting facilities for developing and testing electrical machines.

In the outdoor area of SysTec, a hybrid system test bench was realised. It consists of several generation units (diesel generator 200 kVA, storage units 100kVA and 500 kVA, PV inverter 100 kVA, controllable R-L-C loads banks) and a configurable medium voltage (20kV) test grid, which can operate in an islanded as well as a grid interconnected mode.

A new setup to realise short circuits in low voltage grids was designed and implemented.

In 2017 SysTec plans to extend the hybrid system test bench with a small wind turbine (100 kW rated power), extension of the LV smart grid feeder and extension of the hardware grid simulation capabilities.

### **Services**

- Examination of generation plants (wind energy, photovoltaic inverters, CHP units) in accordance with different grid connection guidelines (low voltage, medium voltage)
- Metrological examination of performance (tripping characteristic) of protection devices at distribution grid components
- Field and laboratory tests of hybrid systems, small wind power plants and individual components as well as tests with hardware emulations under defined operating profiles
- Determination of energy yields and comprehensive characterisation of photovoltaic modules and systems under realistic operational conditions

- Complete investigations and examinations in view of the grid integration and the energy management of electric vehicles
- Investigation of electric vehicles in combination with virtual batteries, also when the vehicle is in operation (roller chassis dynamometer, temperature chamber)
- Real-time distribution grid simulations to test control centers and the grid integration of distributed generators, electric vehicles and power storage (HIL)
- Consulting for smart grid laboratory development
- Measurements of grid quality and analyses of performance



University of Strathclyde (PNDC)





**Power Networks Demonstration** Centre (PNDC) is a research and demonstration facility at the Institute for Energy and Environment (InstEE) of the University of Strathclyde. The main areas of research are asset management, communication and systems integration, network and demand-side management, power electronics and distributed energy. protection and control, sensors and measurement. Among the objectives of PNDC are the development and testing of new technologies and solutions on LV and MV power networks, the development of a realistic and controllable platform for researching and developing useful, innovative electrical transmission, distribution generation and technologies and the creation of a rapid and effective technology pipeline accelerating the proving and deployment of innovative, integrated solutions.

### infrastructure.der-lab.net/ uni-strathclyde



In 2016 PNDC conducted the following activites:

- Prototype testing for overhead line (OHL) sag and collision detection as well as fault passage indicators (FPI), which help improve availability of power systems. These sensor technologies, when integrated with the network operator distribution management system (DMS), offer greater visibility of network conditions during disturbances as they offer more actionable information to the network operators.
- Pre-deployment end-to-end operation verification of a demand-side management (DSM) scheme, using satellite communication, for the Isle of Mull as part of Scottish Government's Community and Renewable Energy Scheme (CARES). A HIL test setup was implemented to extend the physical test system while exchanging real-time simulated data over the satellite communications link to a cloud based aggregator.

These activities inform network operators of innovation which will help ensure reliability in a changing network operation paradigm where a significant penetration of low-carbon generation would mean greater demands on system balancing, protection schemes and unconventional power flows while functioning under the constraints of affordability. So the energy trilemma (low-carbon, reliable, affordable) is very much the driving force.

- Pre-deployment operation verification of MWh rated flow-battery energy storage device for the Isle of Gigha. This energy storage technology was put through its paces to evaluate its functionality which aims to balance intermittent wind generation on the island.
- Characterisation of PV inverters' contribution to fault currents using real PV inverters and subjecting them to network fault conditions. This characterisation allows the development of more accurate inverter models applied to fault studies. Furthermore, a better understanding of the inverters' ability to ride-through low voltage disturbances is obtained to inform the development of new distribution grid codes.

The innovation behind many of the solutions and devices trialed at the PNDC is meeting the functional and performance requirements while being affordable, which will allow mass and cost effective deployment in electricity networks.


PNDC has trebled its real-time simulation capability through the purchase of two new RTDS cubicles. Furthermore, this has been integrated with the PNDC's 1MW motor-generator set to enable PHIL test capabilities. This PHIL capability will be used to evaluate the performance of a wide area control system for the provision of a fast frequency control during large grid disturbances. This test is part of a major national project led by the UK National Grid to improve the system resilience against major generation loss during low grid inertia conditions.

In 2017 PNDC plans to install programmable powerelectronics converters (540 kVA) to emulate devices not represented in its network and to investigate novel converter control algorithms. This installation will be integrated with the existing RTDS to further enhance the centre's PHIL capabilities for low-cost testing the behavior of DER and their impact on the grid.

#### Services

PNDC provides timely input to companies in order to make their technology ready for deployment. This could be through research, testing and demonstration.

#### Partnerships

The PNDC continues to strengthen its partnership with industry. This is evidenced by the new industry members joining the PNDC and supporting the research activity. These include UK Power Networks, Vodafone, CISCO and Yambay. These new members complement the existing PNDC membership base which is committed to the development and accelerated derisking of new smart grid solutions.



#### Accomplishments

The research team of PNDC has recently covered the following topics in their publications:

- Model-Based Analysis Method for Evaluating the Grid Impact of EV and High Harmonic Content Sources
- Incorporating practice theory in sub-profile models for short term aggregated residential load forecasting
- Predicting remaining life of tower steelwork components
- Hardware Testing of Photovoltaic Inverter Loss of Mains Protection Performance
- Prognostics of transformer paper insulation using statistical particle filtering of on-line data

For details please visit:

infrastructure.der-lab.net/ uni-strathclyde

# D-NAP Advancing Wide-Area Protection, Monitoring and Control Systems

University of Strathclyde (D-NAP)



Distribution Network and Protection Laboratory (D-NAP) is a research facility of the University of Strathclyde that comprises a 100 kVA microgrid set with digital partial discharge (PD) detection equipment. The research objectives of D-NAP are demonstration of new techniques for distributed power system control, analysis of the effects of components within a system and testing of protection systems/devices. The facility supports a range of international academic and industrial programmes and has been expanded to incorporate a communications system simulator for testing of smart grid technologies.

> infrastructure.der-lab.net/ uni-strathclyde



In order to advance research on wide-area monitoring, the D-NAP laboratory conducted the following activites in 2016:

- Validation of teleprotection functions over a modern packet-based IP/ MPLS and MPLS-TP wide-area communications networks. This validation ensures that system-critical functions can be delivered reliably over more efficient and flexible infrastructure. It is also of significant interest to utilities which are in the process of migrating to packet-based networks.
- Development performance and characterisation of a novel Phasor Measurement Unit (PMU) prototype. The PMU algorithm is designed to provide very robust measurements of synchrophasors, frequency, and rate of change of frequency, regardless of actual system conditions. Therefore, this provides resilience to unbalance, harmonics, interharmonics, and off-nominal frequency - especially important in future networks with lower inertia and poorer power quality due to distributed generation connected via powerelectronics. Using real-time testing with an RTDS, the PMU prototype typically shows a Total Vector Error (TVE) of approximately 0.01% significantly better than the standard requirements of 1%. The PMU is also computationally efficient, which allows the system to be scaled up cost-effectively.
- Evaluation of convertor controls and varying convertor penetration levels on the GB grid using real-time multirate co-simulation. This is providing greater understanding of the implications of continued renewables connections on systems stability and grid codes.
- Testing the effectiveness of DER sourced time-critical ancillary services using the real-time PHIL co-simulation platform of the D-NAP laboratory. The systems testing capabilities of the D-NAP laboratory have been enhanced through the integration of a PowerMatcher demand side management simulator, PMU based measurements, distributed controls based on the ELECTRA Web of Cells concept and advanced PHIL controlloop delay compensation scheme.



A number of new electrical power research laboratories have been commissioned within a £89M state of the art research and knowledge exchange environment within the Technology and Innovation Centre of the University of Strathclyde. This was recently formally opened by Her Majesty The Queen and His Royal Highness The Duke of Edinburgh.

Of the 45 bespoke laboratories across key research themes of energy, health, manufacturing, and future cities, the following support the power systems research activities of the Institute for Energy and Environment (InstEE):

- Power Electronics, Drives and Energy Conversion Laboratory
- Advanced Sensors Laboratory for nonconventional sensors for the energy sector
- HV testing cells
- DC protection development and testing laboratory

# • D-NAP laboratory:

- New 90kVA Tri-phase unit
- Integration of distributed measurement architecture using advanced PMU devices
- Integration of IEC 61850 GOOSE messaging for laboratory control functionality
- Real-time communications emulation, enabling arbitrary manipulation of Ethernet traffic

# In 2017 the D-NAP laboratory plans:

- Real-time communications emulation integration with real-time digital simulator
- Development and testing suite for low-cost  $\mu\text{-}\text{PMUs}$







Photos: D-NAP

- Technology validation of novel communications
  networks
- Comprehensive testing of power system protection relay settings
- Testing of small DER interfaces and components with PHIL experiments
- Scaled testing of power system controls

# **Partnerships**

In 2016 D-NAP maintained current and developed new partnerships both with industry and research organisations within:

- testing and evaluation projects with industry including Nokia, OTN Systems, CommTel, RTDS Technologies
- projects with European partners including NPL (UK), METAS (Switzerland), LNE (France), VTT (Finland), AIT (Austria), VITO (Belgium), TNO (Netherlands), DTU (Denmark), Tecnalia (Spain), RSE (Italy), OFFIS (Germany), TUD (The Netherlands), CRES (Greece), Fraunhofer IWES (Germany), SINTEF (Norway), and IPE (Latvia)

### Accomplishments

In 2016 the D-NAP team carried out research an a range of topics with subsequent publications, such as:

- "Automatically Detecting and Correcting Errors in Power Quality Monitoring Data", S. M. Blair, C. D. Booth, G. Williamson, A. Poralis, and V. Turnham. IEEE Transactions on Power Delivery, 2016
- "Controller HIL testing of real-time distributed frequency control for future power systems"E. Guillo-Sansano, M.H. Syed, A.J. Roscoe, G. Burt, M. Stanovich, K. Schoder. IEEE Innovative Smart Grid Technologies 2016 Europe Proceedings. IEEE, Ljubljana, Slovenia.

For more details and a complete list of publications please visit:

infrastructure.der-lab.net/ uni-strathclyde











# SANDIA Towards Cyber-Secure Power Systems



Sandia National Laboratories (Sandia DETL)



National Laboratories Sandia is a multimission engineering and science laboratory with major R&D responsibilities in the US national security, energy and environmental technologies, and economic competitiveness. Sandia is managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the US Department of Energy's National Nuclear Security Administration.

The Distributed Energy Technologies Laboratory (DETL) of Sandia emphasises issues related to grid interconnectivity, controls, security, safety, performance, reliability and interoperability. DETL conducts research on generation, storage, and load management at the component and systems levels and examines advanced materials, controls, and communications to achieve a reliable, low carbon electric infrastructure.

# infrastructure.der-lab.net/sandia



Sandia National Laboratories conducts a range of DER and power systems research projects including:

- PV and energy storage system grid-support function evaluations and interoperability tests. Results are used to advise the development of grid interconnection standards (e.g., IEEE 1547) and certification standards (e.g., UL 1741). The experiments include PV inverter and multiple-inverter anti-islanding, frequency and voltage ridethroughs, volt-var, frequency-watt, fixed power factor, connect-disconnect, etc.
- Work with the SunSpec Alliance and Smart Grid International Research Facility Network (SIRFN) labs to create an open-source, common testing platform for the advanced DER to automate the certification process and create drivers for PV simulators, grid simulators, data acquisition systems, DER under test, and other power equipment.
- Control simulation and field demonstrations for dampening inter-area oscillations in power systems (small signal stability in the frequency range of 0.1-1Hz). Sandia has successfully completed closed-loop testing of this controller with the Bonneville Power Administration to dampen oscillations on the WECC DC intertie.
- Validate control architecture capable of handling pulsed loads using the Secure Scalable Microgrid Test Bed. Results are used to guide the development of the allelectric warship project on behalf of the US Navy.

# **New capabilities**

In 2016 Sandia installed OPAL-RT PHIL and Typhoon HIL (CHIL) systems in DETL. The PHIL system has initially been configured for transmission modelling of inter-area dampening controllers and advanced distribution management system (ADMS) controllers. **The Typhoon** HIL system has been integrated with the Austrian Institute of Technology (AIT) Smart Grid Converter (ASGC) and AIT SunSpec Server for advanced inverter function experiments. By using the SunSpec System Validation Platform, automated certification tests of the ASGC according to UL 1741 SA and other grid codes can be conducted quickly and accurately.

An internally funded Cyber-Renewable-Grid Project integrates Sandia's strengths in DER, visualisation, Emulytics, and cyber security red teaming to support advanced grid experiments with a powerful, versatile physical/virtual network. These integrated capabilities will allow Sandia to validate security, risk, optimisation, and controls research results involving grid-interconnected components, renewable energy systems, demand response assets, and communication/control networks with

both physical and emulated devices. The integrated research platform connects DER resources and data acquisition systems with cyber security, HIL, risk analysis programs, and visualisation tools to execute high-impact R&D. The network links not only the physical assets (PV, energy storage, wind, smart meters, etc.) and emulated devices and networks (e.g., MiniMega, SCEPTRE, OPAL-RT, Typhoon HIL), but also the staff with diverse skillsets necessary to complete multidisciplinary research at the forefront of cyber-physical security, renewable energy, and electric power systems required to assist the nation in transitioning to a smarter power grid.

Sandia will also be demonstrating a cyber-secure virtual power plant in 2017 that will provide stochastically optimised offers to different energy and reserve markets and generate the commitment in real time. The optimisation and dispatch of multiple physical and emulated renewable DER assets will be conducted at DETL over a TCP/IP network with real-time cyber analytics ensuring the DER assets will reliably provide power.



Collaboration with Sandia National Laboratories and other US National Laboratories is encouraged in areas of mutual research interest. There are multiple technology partnerships options for working with Sandia. For more information, please see "Technology Partnerships" at sandia.gov/working\_with\_sandia

# **Partnerships**

Under ISGAN Annex 5 SIRFN, Sandia has been actively participating in PV and energy storage test protocol development projects.

In 2016 Sandia and AIT initiated a joint project to introduce CHIL testing in the SIRFN advanced inverter testing activity. For this pupose, the AIT Smart Grid Converter was deployed at Sandia's DETL and is being used as a reference test object to develop and validate new test procedures for the automated testing of advanced grid support features of inverters (see p. 45 for more information on this collaboration).

#### Accomplishments

#### Awards:

- Federal Laboratory Consortium 2017 Award for Excellence in Technology Transfer for New Jersey TRANSITGRID project
- 2016 Albuquerque Section IEEE Outstanding Young Engineer Award - Jay Johnson

# Patents:

- "Systems, methods and computer program products for electric grid control" J. Johnson, M. A. Smith, D. A. Schoenwald, M. E. El-Khatib. Patent Application 15/425,815, 6 February 2017
- "Arc Plasma-Generating Systems and Methods Thereof" E.J. Schindelholz, K.M. Armijo, J. Johnson, R.K. Harrison, B.B. Yang. Patent Application 15,603,782, 24 May 2017

# **Publications:**

- "Outdoor Field Performance from Bifacial Photovoltaic Modules and Systems" J. S. Stein, D. Riley, M. Lave, C. Deline, F. Toor. 44th IEEE Photovoltaic Specialists Conference. Washington, DC
- "Photovoltaic Frequency-Watt Curve Design for Frequency Regulation and Fast Contingency Reserves" J. Johnson, J. Neely, J. Delhotal, M. Lave. IEEE Journal of Photovoltaics, vol. 6, no. 6
- "PV Performance Modeling Methods and Practices: Results from the 4th PV Performance Modeling Collaborative Workshop, International Energy Agency Photovoltaic Power Systems Programme" J. S. Stein. IEA-PVPS

For more details and publications please visit:

# infrastructure.der-lab.net/sandia





Photos: Sandia National Laboratories



Technical University of Denmark Department of Electrical Engineering (DTU)



The **Department of Electrical Engineering of the Technical University of Denmark (DTU)**, one of the leading technical universities in Europe, educates engineers within electrical engineering technologies and biomedical engineering. DTU has a large portfolio of projects in the field of renewable energy.

SYSLAB of DTU is a flexible intelligent DER laboratory. Among other DTU's facilities are the Center for Electric Power and Energy (CEE), which aims to transform the electric power system into a reliable, cost-efficient and sustainable system based on renewable energy, and the Electric Vehicle Lab (EV Lab), which supports a wide array of EV integration and technology services.

# infrastructure.der-lab.net/dtu



Throughout 2016 DTU has been been further developing power system testing methodologies. The focus has been on performance verification of ancillary services delivered by DER unit via an aggregator. This activity supports the foundation for financial settlement of service delivery from DER taking into consideration requirements for service specification and methods for assessing degree of delivery considering the baseline consumption. The work continues towards a pre-qualification framework for aggregators for certification before they are deployed in the system.

#### **New capabilities**

The SYSLAB facility, part of PowerLabDK, has been extended with a heat system supplying heat to two houses via a common water based heat system. Heat can be the generator via a heat pump or controllable electrical boiler units, and it can be configured in a very flexible way. This allows for experiments combining water based common heat systems such as district heat systems with the electrical system to study improved integrated of variable renewable energy using flexibility in the heat system.

In 2017 it is planned to extend SYSLAB with a real small-scale district heating system that will include several buildings, such as offices, lab buildings and family houses. This will enable studies of integrated energy systems and thus improve the capabilities for power system testing to even more real situations including heat side flexibility.



# Accomplishments and partnerships

Several external researchers have visited SYSLAB and conducted investigations on coordinated control of various combinations of DER components using different control structures and controllers. This has included agent-based control as well as classical hierarchical control. The visits have resulted in joint research publications.

SYSLAB has also been used for demonstrations in connection with public conferences.





# Storage System Supporting Frequency Regulation at EDF



Electricite de France -Research and Development (EDF)



Main objectives of **EDF**'s R&D are fostering innovations, cutting CO2 emissions by developing alternatives to fossil fuels, and building safer power grids. EDF implements a proactive policy of partnership and exchange with clients and laboratories in France, Europe, and all over the world. The research and development branch of EDF contributes to the performance of the operational crews of EDF and aims to identify and prepare levers for growth in the medium to long term. In 2016, just as before, Concept Grid has had a wide range of testing campaigns. By its conception, Concept Grid allowed very different topics to be studied: transformers with OLTC, voltage regulators, smart recloser, simulation, storage, and others.

Storage was a key topic of the activities at Concept Grid in 2016, in particular regarding frequency regulation. **Concept Grid has been equipped with a 1 MW battery system which has been tested**  in regular and disturbed condition. In addition, it has allowed the research team of Concept Grid to develop their own command laws, as well as earn corresponding expertise and win a number of industrial calls for tenders.

Besides that, Concept Grid also focused on microgrid topics in 2016 and should continue so in 2017 as well: in particular, energy management systems are expected to be tested.

# **New capabilities**

Concept Grid has taken advantage of the **newly installed 1 MW Li-ion battery system**. 2016 has really been the year of full testing with this system.

In addition, simulation has been enhanced through the purchase of new licenses for real-time simulation. In 2017 Concept Grid will be developing further and enhancing its co-simulation activities.

Regarding the hardware, Concept Grid welcomes a new storage system in 2017: 120 kW flywheels developed in partnership with Stornetic. The system will be installed on the LV network to perform tests, characterise this system, develop command laws and study its integration in the field under both normal and disturbed conditions.



infrastructure.der-lab.net/edf



Concept Grid is still open to long-time collaboration as well as "one-shot testings": DSOs, manufacturers, universities, researchers are welcome to test in real conditions devices and solutions which could be impossible to fully test in the field.

Concept Grid's mission is to boost development and derisk these solutions. If any doubt subsists regarding a new technology, Concept Grid is the tool to challenge it and get a clear vision on its effectiveness.

#### Accomplishments

Concept Grid has been strongly involved in Venteea demonstrator. 2016 has seen the closing meeting of this important project in Troyes (FR), with a complete focus on the Concept Grid contribution.

In 2016 Concept Grid presented the publication "Islanding tests with Li-ion storage system on the EDF Concept Grid" by Benoît Puluhen & al. at the CIRED Workshop 2016 within the contribution to the Nice Grid demonstrator.

# **Partnerships**

The German manufacturer Stornetic designed flywheels for Concept Grid to be installed and tested in 2017.

The national railway company SNCF has signed a framework contract with EDF in 2016. Concept Grid is involved in the emulation and validation of a hybrid railway substation.

Currently in progress are activities regarding disturbances characterisation with the French reference laboratory of metrology LNE.

With RWTH Aachen University Concept Grid has tested different co-simulation methodologies.



# **Accelerating Systems Integration at**

# **HESI Facility of TNO**





**TNO** is a knowledge organisation for companies, government bodies and public organisations. In the area of sustainability and energy, TNO works with commercial players and the government to develop and integrate knowledge of intelligent energy networks and smart grids. The focus lies on durable, balanced and costeffective solution strategies for energy reduction, renewables integration and sustainability issues. The skills and knowledge provided by TNO create tools that enable energy planning, decision support, implementation strategy, and scenario assessment. Among the available facilities are a climate chamber, a nanolab, a cyber security laboratory, a sensor network living laboratory, a vehicle hardwarein-the-loop (VEHIL) laboratory, and the newly opened HESI facility.

# infrastructure.der-lab.net/tno



In January 2017 TNO opened its HESI facility (Hybrid Energy System Integration Facility). HESI's main target are system integration issues that play a key role in accelerating the transition of electricity, heating and gas systems in terms of how they relate to each other. The facility supports SMEs and energy companies in developing and testing smart energy systems for everyday use in large-scale deployments. The infrastructure can be used for rapid prototyping and testing of energy system configurations, interdependent of the larger energy

system. HESI's unique features are a consistent mapping between realtime environment and simulation environment, its suitability for optimisations in hybrid energy context (gas, electricity, heat) and its interconnectivity with other smart grid lab environments for sharing applications, distributed control, and more. Furthermore, there is a data and communication infrastructure and advanced ICT solutions for monitoring and controlling energy systems.

#### Services

At HESI at the EnTranCe test site in Groningen, companies can test and improve the behaviour and robustness of new energy-related technologies, products and services. **HESI offers research institutes**, **utilities**, **equipment manufacturers and other parties in the energy sector a hybrid**  (electricity, heat and gas) energy environment for testing all kinds of innovations in an integrated way. Coupled with TNO's knowledge of ICT, privacy and data security, the HESI facility helps companies to get from prototype to market faster.





In 2017 HESI plans to focus on facilitating ongoing projects but is also looking forward to incorporate new hybrid energy solutions, DC systems and appliances.

# Partnerships

In early 2017 the HESI facility was fully equipped and prepared for use at the EnTranCe site where TNO is cooperating with Hanzehogeschool Groningen, the University of Groningen and Energy Academy Europe. Companies from the energy sector grid operators GasUnie and GasTerra, have also committed to the EnTranCe initiative. This offers government, research institutes and industry the opportunity to cooperatively innovate in the energy sector. Internationally, the HESI facility cooperates with other DERIab members: EnergyVille in Belgium and the American National Renewable Energy Laboratory (NREL), with whom TNO signed a cooperation agreement at the opening of HESI.

Last but not least, TNO is glad to join the DERlab member network in 2017 and looks forward to the cooperation.







National Technical University of Athens - Institute of Communications and Computer Systems (ICCS)



The Institute of Communications and Computer Systems (ICCS) is associated with the Department of Electrical and Computer Engineering (ECE) of the National Technical University of Athens (NTUA). The research and development activities of ICCS all evolve around different aspects of telecommunications. computer systems and techniques and their application in a variety of areas such as electric power systems, software and hardware engineering, control systems and biomedical engineering.

Among the research groups of ICCS are the Electric Energy Systems Laboratory (EESL), which offers experimental training for students, and Smart RUE, which focuses on smart grid research.

#### infrastructure.der-lab.net/iccs



In the NOBEL GRID project ICCS/NTUA developed a three-phase and singlephase battery inverter with several sophisticated control algorithms. The validation and testing procedure of the developed battery inverter was based on HIL experiments. More specifically, the proposed testing chain consisted of offline/software simulations, CHIL and PHIL experiments.

Bidirectional DC-DC Converter for grid connected and islanded operation			
PI Based control algorithm for bidirectional power flow			
Bidirectional voltage source converter (DC-AC) for grid connected operation		Bidirectional voltage source converter (DC-AC) for islanded operation	
1. 2. 3.	Synchronous reference frame PI based approach Virtual Resistance active damping method Grid current feedback damping method (2DOF)	1. 2. 3.	Synchronous reference frame PI based approach Proportional - Resonant control strategy Optimal control based on H-infinity approach
			Developed and tested

battery inverter control algorithms

Moreover in the NOBEL GRID project a coordinated voltage control algorithm (CVC) for distribution networks was developed. The optimisation problem that the CVC algorithm handles was a Mixed Integer Non-Linear Programming (MINLP), and the output was an optimal solution to voltage rise (due to high DG penetration) and voltage drop (during peak load periods) problems considering the number of on-load tapchanger changes and power losses. The CVC algorithm was tested in a CHIL environment. Validation of the proposed CVC algorithm through combined CHIL and PHIL tests were completed in 2016.

During 2016, ICCS/NTUA was active in DC microgrids and specifically in a seamless interchange between interconnected and islanded operational mode. Offline/software simulations as well as HIL experiments were performed concerning islanding detection and seamless transition capabilities of DC microgrids.

Furthermore, ICCS/NTUA is a partner in the ERIGrid project. One of the project objectives is to implement cosimulation among software of different purposes. First step in this direction was to implement a co-simulation between a multipurpose simulator and a communication simulator. The multipurpose simulator generates data and feeds them in to the communication simulator for further processing.

Laboratory exercises for NTUA's students were designed and performed with the use of PHIL simulation in a systematic way. The topics focus on the effects of increased integration of DG, namely power sharing between synchronous generators and DG, voltage control with On Load Tap Changer (OLTC) and DG, short circuits with inverter-based DG and microgrid operation. A double PHIL configuration was developed that created two work benches for the students in order to allow handson experience in small groups (5 or 6 students each). Experiential learning was applied following Kolb's learning cycle of concrete experience, reflective observation, abstract conceptualisation and active experimentation.









In 2016 ICCS/NTUA has implemented the following new equipment:

- Spitzenberger & Spies PAS 5000: Linear amplifier - Grid simulator with nominal power of 5kVA, capable of 4 quadrant operation and high bandwidth (DC - 5kHz). The linear amplifier is a hardware upgrade of the existing PHIL testbed. With the new amplifier PHIL experiments with DC hardware devices and Multiple-Input Multiple Output (MIMO) PHIL experiments are now possible.
- PM15A30F03 Triphase power module: 3 channel DC-DC converter from Triphase NV with 15kW total nominal power, fully programmable in Matlab/Simulink. The DC-DC converter was part of the developed battery inverter of the NOBEL GRID project and was used as well in other activities mainly related to PHIL experiments.
- Regatron Photovoltaic Simulator: The PV Simulator used in many PHIL experiments is a three channel DC power supply with 3x10kW nominal power. Using the dedicated software environment the user is capable of utilising fully controllable PV characteristics V-I curves.

### In 2017 ICCS/NTUA plans:

- Construction of a DC microgrid: The DC microgrid will consist of a photovoltaic simulator, batteries and some loads. The DC microgrid will be connected through an AC/DC inverter to the utility grid but also through the linear amplifier to simulated networks running in the Real-Time Digital Simulator. In this context, advanced control schemes for DC microgrid operation will be examined.
- Construction of a HIL testbed for studying regenerative braking storage systems in DC railway systems.
- Implementation of co-simulation between a power system, a communication system and a controller, in order to test realistically a voltage control (VC) algorithm.



ICCS/NTUA offers a range of services in the following research areas:

- Grid management in mainland system
- RES integration
- New technologies and smart grids
- Grid management of non-interconnected islands of Greece

In regards to the above-mentioned services, ICCS/NTUA maintains a strong collaboration with the Hellenic Distribution System Operator.

# Accomplishments

In 2016 ICCS/NTUA performed research on a number of topics with subsequent publishing:

- Laboratory Education of Modern Power Systems using
  PHIL Simulation
- Testing Local and Coordinated Voltage Control Approaches with CHIL and PHIL Simulation
- CHIL and PHIL simulation for testing modern distribution network control and DER

For more details and publications please visit:

# infrastructure.der-lab.net/iccs



# **TECNALIA Extending Testing Services**





**TECNALIA** Research & Innovation is the first private research, development and innovation (R&D&I) organisation in Spain and one of the leading ones in Europe. TECNALIA offers technological services, testing and certification, R&D&I projects, transfer of industrial property, business promotion, business diversification, innovation management and foreign support.

Among many other experimental facilities, the Energy and Environment Division includes a Smart Grids Area, a High Power Laboratory, a High and Low Voltage Laboratory, and a Distributed Energy Resources Laboratory equipped with several types of generation, storage and controllable loads, including an electric vehicle platform and a smart metering test bench.

# infrastructure.der-lab.net/tecnalia



#### Safety requirements for power electronic converter system and equipment

TECNALIA is about to finish the development of a 4-quadrant fully programmable voltage source in the power and voltage ranges of up to 1.25 MW and 3300 V respectively. It allows varying the frequency of the output voltage from 0 to 75 Hz as well as generating programmable sets of voltage harmonic components up to the 10th harmonic. This equipment is the core of the Laboratory THOR.

This infrastructure is a flexible grid intended to be used as a grid emulator to facilitate the testing of power converters at a full/significant scale. It allows manufacturers to perform tests of the power converters and control units during the development stages of the product, with the idea to fulfil the requirements stated in the grid codes of each country. Laboratory parameters are controlled by a SCADA system. The way to programme the events is completely flexible, including the possibility of introducing input data files provided by the customer (generated at their facilities or field data).

The performance of the infrastructure allows the manufacturers to characterise their products at a relevant power in a friendly environment prior to connection to the grid.

Flexible Grid THOR Laboratory is designed to test equipment like:

- Wind converters
- Grid power quality devices: STATCOMS, FACTS, active filters
- Energy storage converters
- Traction converters

# Services

TECNALIA provides its expertise and thorough knowledge on various grid codes and their implications in the above mentioned tests. In the context of the new infrastructure and the possibility to carry out real testing on the THOR platform, TECNALIA offers consulting services in the field of grid code compliance, as well as:

- Safety of power converters for use in photovoltaic power systems according to IEC 62109-1/2
- Safety requirements for power electronic converter system and equipment according to IEC 62477-1



- Field verifications of I-V curves of photovoltaic strings and modules
- New walk-in high-low temperature test chamber:
  - Test space dimensions (WxHxD): 2640 x 2400 x 4160 mm
  - Temperature range: -45°C to 85°C
  - Humidity range: 10% to 95% RH
- High temperature conductor and accessories testing services according to IEC 61238-1

The following tests on Power Converters Under Test (PCUT) can be carried out at the THOR Laboratory:

- Voltage and frequency variations: Most grid codes require the devices/farm to work within a normal operation range of voltage and frequency. Generation systems based on power electronics make total inertia of the system decrease and additional active power control loop may reduce this effect. In this context, THOR can emulate voltage and frequency variations to assess the behaviour of the PCUT in normal operation, as well as the active (Pf) and reactive (QV) control loops implemented to satisfy the grid code requirements.
- Reactive power control behaviour: Most grid codes require to work with reactive power and/or power factor targets defined by the system operator.
- The objective of this test is to assess the behaviour of the PCUT with different reactive power / power factor target.
- Active power control behaviour: The objective of this test is to check the behaviour of the PCUT under active power variations both due to resource variability or to respond to active power target modification (maximum active power ranges are included in many grid codes, also when the system operator requires a reduction of generation).

#### Accomplishments

Based on multi-level topology TECNALIA developed a programmable voltage source. The topic is presented in several publications:

- Modulation Strategy for Multiphase Neutral-Point-Clamped Converters
- Generalised PWM-Based Method for Multiphase Neutral-Point-Clamped Converters With Capacitor Voltage Balance Capability

For more details please visit:

# infrastructure.der-lab.net/tecnalia

- Faults: THOR allows the implementation of programmable voltage dip profiles. Therefore it allows to analyse the behaviour of the PCUT under the voltage dips specified by each country's regulation.
- Harmonics: THOR can generate fully programmable sets of voltage harmonic, allowing assessing the performance of the PCUT under the harmonic conditions described by each country regulation.
- Flicker: Grid codes limit Pst and Plt values. The infrastructure is able to perform flicker calculation.



# **CRES Contributing to Microgrid Enhancement**



Centre for Renewable Energy Sources and Saving (CRES)



The **Centre for Renewable Energy Sources and Saving (CRES)** is the Greek organisation for RES, RUE and energy saving (ES). Its main goal is research and promotion of RES/RUE/ES applications at national and international levels, as well as support of related activities in the context of sustainable development. CRES offers applied research and technical support to RES sectors such as geothermal energy and active solar systems amongst others. Main research activities of CRES regarding power system testing and co-simulation in 2016 were undertaken in the frame of the EU funded projects ELECTRA IRP and ERIGrid.

In the frame of the ERIGrid project CRES is involved in the analysis of cosimulation tools, such as FMI and Mosaik, and in the development of scenarios to be implemented with these tools. In ELECTRA IRP the CRES research team performed simulation tests of power systems under various scenarios of dynamics and under implementing control algorithms developed in the project. The main subject of these tests regarded primary frequency regulation with various types of controllers such as classic droop, fuzzy controllers and adaptive frequency control. Based on the results of the analyses, CRES released several publications, including a submission to the CIRED 2017 conference.

#### **New capabilities**

In 2017 CRES plans an upgrade of their microgrid SCADA system so as to accommodate control algorithms developed and implemented on Matlab/ Simulink. This upgrade is expected to enhance power system testing capabilities by effectively incorporating complex algorithms in the test facility. It will also provide a means of connection of physical devices to a simulation platform that is to be used for co-simulation purposes among others.

#### **Partnerships**

CRES is a member of the ELECTRA IRP consortium. During 2016-2017 CRES has been involved in the finalisation and evaluation of the concepts developed in the project. CRES also contributes to exchange of expertise by participating in the ELECTRA Researcher Exchange Program and the Transnational Access activities in the ERIGrid project, both with external researchers and within the consortia.

Member of the EERA JP Smart Grids, CRES is also active in various research and networking activities in the EERA context.



infrastructure.der-lab.net/cres



CRES and in particular the department of PVs and Distributed Generation offer a range of services:

- Characterisation of PV cells, modules, panels etc. in terms of I-V curves, conformance to relevant standards and expert opinion on the performance and health state of field PV modules
- Characterisation of PV inverters performance in terms of efficiency and protection, and conformance to relevant standards
- Characterisation of battery cells and conformance to relevant standards
- Performance evaluation and characterisation of distribution grid components, i.e. load controllers, inverters, control algorithms, power quality issues
- Investigation of microgrid operation scenarios including islanded or grid-connected operation and Demand Side Management strategies, energy and cost optimisation studies
- Evaluation of control architectures, i.e. central, distributed, decentralised control schemes

# Accomplishments

In 2016 CRES filed an international patent for the concept "Apparatus and control method of self organised operation of distribution grid sections without new physical communication infrastructure".

CRES recently performed a number of studies, with subsequent publishing:

- An experimental case study: Stochastic model predictive control for economic/environmental operation management of microgrids. This study deals with the implementation and evaluation of a Model Predictive Controller that performs a cost optimisation of the operation of a microgrid. The algorithm was implemented and tested on the experimental microgrid at CRES during the Transnational Access activity of the EU-funded project DERri
- Forecasting and observability: critical technologies for system operations with high PV penetration. This study deals with forecasting methods implemented for the prediction of the production by PV systems

For more details please visit:

# infrastructure.der-lab.net/cres



CRES Pikermi microgrid system diagram

# University of Manchester: from Desk-Based Simulations to Lab and Site Tests



University of Manchester



The University of Manchester

The Electrical Energy and Power Systems (EEPS) and Power Conversion (PC) groups at the School of Electrical and Electronic Engineering of the University of Manchester are at the forefront of research and teaching in the field of electric power engineering. Particular areas of competency of the EEPS group include transformer insulation and monitoring, polymeric insulation and power system transients. The PC group focuses on future networks, with research into design and operation of powersystem plant, transmission networks, and smart low-carbon distribution networks, and the development of HVDC expertise.

# infrastructure.der-lab.net/ uni\_manchester



In 2016 research activities associated with power system testing and co-simulation at the University of Manchester can be grouped as those related to HV, RTDS and power conversion laboratories:

# HV:

Desk Based Analysis

- Assessment of new tower, conductor and cable designs
- Electromagnetic field and interference studies
- Earthing analysis
- Failure analysis using FEA methods (electrical, thermal and multi-stress)

# Laboratory Testing

- Noise and corona analysis
- Insulation system development and testing
- Condition monitoring of HV plant (switch gear and transformers)
- Assessment of new materials
- Forensic analysis

### Site Testing

- Asset management techniques
- Long-term tests and data acquisition

#### RTDS:

- Wide area monitoring, protection and control assessment for stability, dynamics and performance analysis for distributed power systems
- Power and energy network topologies of smart grid
- IEC61850-8-1/-9-2 process bus architectures
- DNP3/IEC60870-5-104 SCADA communication
- IEEEC37.118.1/ RTDS/GTNET PMU Synchrophasor data streaming and PMU-WAM control and protection with Phasor Data Concentrators PDC, GPS synchronisation 1PPS, IRIG-B, IEEE1588
- HVDC for industry-standard multi-terminal HVDC/MMC controls system

#### **Power conversion:**

- Energy storage and electrical system integration
- Superconducting fault current limiters
- Power electronics and electrical machine design
- Condition monitoring

The outcomes of these research activities are detailed simulations, tests, and analyses of electrical systems (e.g., lines, transformers, batteries, distribution and transmission networks, etc.), which provide an increased understanding of the characteristics and constraints of these systems under given conditions. More specifically, current research focuses on understanding the requirements to ensure the reliable and sustainable supply of energy in increasing quantities, while also meeting the desire for reduced environmental impacts.

Innovation, in terms of new research and testing techniques, plays a vital role in ensuring we meet the challenges associated with increased energy demand and changing generation mixes.

# Partnerships

Several partnerships with different research and industrial partners are constantly established through collaboration in different research projects. Currently, the university collaborates with several DERlab members (e.g., the University of Strathclyde, Fraunhofer, etc.), as well as with other research and industrial partners (Alstom, ENWL, Scottish Power Energy Networks and Schneider electric, among others) as part of several European and UK projects, such as: VISOR, NIA; EFCC, NIA; MIGRATE, H2020; DACforDTI/FIP, EPSRC; UPSIDE: Virtual Energy Store, Innovate UK; Manifest, EPSRC; integration in distributed networks.

# Services

The University of Manchester offers a wide range of consulting services, particularly for electricity companies (e.g., National Grid and Electricity North West), from desk based simulations to laboratory and site tests, in line with the facilities and research interests of the university.

# **New capabilities**

#### HV:

- 20 kVA high current source (configurable to maximum current of 10 kA)
- Salt fog and environmental test chambers
- Modern digital measurement equipment
- RIV measurement systems
- Material processing and characterisation equipment
- UV inspection facilities for corona monitoring
- High voltage environment chambers for testing of equipment in harsh environments
- Anechoic chamber, with 200 kV input for noise and corona measurements on novel conductors

# **RTDS:**

• These labs comprise 6 x RTDS simulator racks with integrated capacity of 30 x PB5 core processors and 5 x Modular Multi-level Converters MMC support units

#### Power conversion:

- 240kW and 180kWh AC-grid connected energy storage system with a real-time control platform interface
- 1MJ supercapacitor-based energy storage system
- NH Research 9200 battery tester
- ESPEC AR680 environmental chamber

In 2017 the University of Machester plans to improve their RTDS capabilities:

- Development of IEC61850, C37.118 and IEC 60870 digital substation communication protocols with interoperability schemes
- Development of new concepts for WAM protection/control
- Innovation of new prototypes for SMART transmission/distribution
- Validation of smart grids for future low-carbon energy storage, distributed generation concepts for smart grids integrated systems with renewable energy storage asset management strategies
- Validation of multi-terminal HVDC/UHVDC control strategies for transmission/ distribution systems, HVDC wide area control schemes for enhanced power stability and sub-synchronous resonance reduction of multiple-HVDC links, HVDC active power flow modulation optimisation for next generation AC transmission networks, VSC-HVDC/FACTS integrated control schemes for STATCOM, UPFC and TCSC compensation control schemes, multi-terminal VSC-HVDC systems control strategies for offshore wind farm integration, etc.

# Accomplishments

Due to the strong research focus, the main accomplishments of the University of Manchester are in terms of publications and research grants. More information about the university's research facilities, staff, publications, and research grants at

> infrastructure.der-lab.net/ uni\_manchester



at the University of Manchester



# **RSE Upgrading Microgrid Research** Capabilities



Ricerca sul Sistema Energetico (RSE)



Sistema RSE SpA (Ricerca sul Energetico) carries out publicly funded national and international programmes in the fields of electrical power, energy and the environment. RSE conducts research on three main areas: all aspects linked to the sustainable development of the Italian electrical power network and related infrastructures, the safe and effective use of primary sources of energy, as well as power generation, transport and distribution, and end-use energy efficiency.

The activities cover the entire supply system with an application-oriented, experimental and system-based approach and are aimed at developing new initiatives to provide concrete solutions to the needs expressed by stakeholders, the market and the general public.

#### infrastructure.der-lab.net/rse



The main activities on power system testing carried out in the RSE DER Test Facility (TF) are related to microgrid island operation and aggregated resources remote control by local DSO.

Microgrid island operation research activities have been performed implementing in different storage systems converters, voltage and frequency control algorithms (droop controls) that enable the transition from on-grid to off-grid operation and stable operation in islanded condition also with generation and load variation. In addition, specific control algorithms have

been developed in order to control main grid re-connection phase enabling a very fast and safe procedure.

Microgrid remote control allows to manage, from the point of common coupling, the microgrid as an aggregated DER, implementing grid services as active and reactive power needed for voltage and frequency regulation. The activity, performed in collaboration with the local DSO, demonstrated that microgrid (and the aggregated DER) control from primary substation is possible and also reliable when connected to a public DSL line.

#### **New capabilities**

New equipment installed in DER TF in 2016 includes a CHP gas engine (50kWe, 80kWt), new PV modules and PV inverters that replaced the old installation and an innovative "intelligent" breaker that allows automated synchronisation control.

In 2017 DER TF plans to install a new system based on innovative capacitors in order to implement a storage system dedicated to manage grid ancillary services.

All capabilities are used for power system testing. In particular, the CHP engine, powering a synchronous generator, allows active and reactive power control and it is operated as one of the microgrid aggregated resources.





# **Partnerships**

In 2016 RSE's DER TF developed the following partnerships:

- Loccioni (system integrator) and TDE-Macno (converter manufacturer) in regards to storage system integration, advanced control function and island operation
- ABB in regards to innovative breaker testing for island operation and re-syncronisation control
- Unareti (DSO) in regards to aggregated microgrid remote control from primary substation

#### Accomplishments

In 2016 RSE published on a range of topics, such as:

- Daily and Short Term Optimal Energy Management with Uncertainty
- A Photovoltaic Production Estimator based on Artificial Neural Networks

For more details and publications please visit:

# infrastructure.der-lab.net/rse





# INESC TEC Developing Multi-Temporal Optimal Power Flow for Managing DER



Institute for Systems and Computer Engineering, Technology and Science (INESC TEC)



The Institute for Systems and Computer Engineering, Technology and Science (INESC TEC) is a private non-profit institution having as associates the University of Porto, INESC and the Polytechnic Institute of Porto. The institute was created to act as an interface between the academic world, the world of industry and services and the public administration in information technologies, telecommunications and electronics (ITT&E).

The research on power and electrical energy is mainly led by the Power Systems Unit (USE) which areas of expertise are the integration of wind power and renewable energy in general in power systems along with distributed generation and smart grids.

infrastructure.der-lab.net/inesc\_tec



In 2016 INESC TEC performed a range of activities in the field of power system testing and co-simulation:

- Implementation of a centralised voltage control algorithm for LV microgrids embedded in the MicroGrid Central Controller (MGCC) for managing DER such as storage devices or PV microgenerators in a coordinated way
- Development of a bi-directional matrix converter prototype for energy storage applications
- Development of a power converter for energy store applications with FRT capability.

# **New capabilities**

In 2016 the laboratory was upgraded with a fully programmable source/sink DC system capable of emulating battery banks, PV arrays and similar elements with up to 15 kW.

The laboratory also acquired a highperformance real time simulator (OPAL-RT OP 5600) that is connected to an external power amplifier for PHIL testing. For 2017 INESC TEC plans:

- Development and testing of a Multi-Temporal Optimal Power Flow for managing DER, namely storage devices and flexible loads to control voltage in a LV microgrid. Software prototype is to be developed and tested in the laboratory at the level of central systems.
- Implementation of a reduced scale model of a distribution network for PHIL testing purposes



#### **Partnerships**

The laboratory is accommodating extensive testing of network applications and prototypes developed under the H2020 European project SENSIBLE. The tests will support the future deployment in a real demonstrator in Évora, Portugal (in collaboration with EDP and SIEMENS). The tests conducted at INESC TEC include the implementation of a laboratory scale LV network (0,4 kV), composed of LV cable simulators, loads and DER connected to both commercial converters and prototypes developed in the lab.

#### Accomplishments

In 2016 the research team of INESC TEC released the publication "Experimental validation of smart distribution grids: Development of a microgrid and electric mobility laboratory", C. Gouveia, D. Rua, F. Ribeiro, L. Miranda, J.M. Rodrigues, C.L. Moreira, J.A. Peças Lopes, International Journal of Electrical Power & Energy Systems, Volume 78, pp. 765-775, June 2016.

For more details please visit:

#### infrastructure.der-lab.net/inesc\_tec







The new NetPower DemoLab of the **University of Luxembourg** carries out experimental verification of RTD works towards full-scale accommodation of solar derived power generation at all voltage levels of the grid for Luxembourg's utility CREOS. Supported by FNR, as a national cooperation platform for the University's Electrical Engineering Institute, its Interdisciplinary Centre SNT and its CSC Research Unit, it broadens to the national RTD centre LIST.

> infrastructure.der-lab.net/ uni\_luxembourg



As an integral part of Luxembourg's strategic reorientation towards smart networks, the NetPower DemoLab lays the ground for:

- solving emerging tasks in the transition to active power grids in Luxembourg in the next two decades
- contributing to and profiting from international cooperation
- certification of components power/ communication compliance

The NetPower DemoLab's structure in the computer aided engineering process is combining real and virtual testbeds progressing from offline to online testing. For SCADA security testing, a virtual topology of the CREOS network is implemented in the lab. CREOS contributed three breakout panels, a rack, network connectivity and power supply. The NetPower DemoLab equipment covers real-time software simulation backed up by fast FPGA-signal processing hardware, extended to real-physics electrical power in the 100kVA range.

This allows for close reproduction of grid dynamics, electricity storage, electromechanical conversion and power electronics units as well as of the major real-time fieldbus protocols, thus allowing for safety, security and reliablity testruns of networked SCADA systems complex virtual environment in and failure scenarios. Verification of prototypical solutions is a key barrier in engineering multidisciplinary construction of hardware and software to become reliable in given varieties of complex system environments.



- Installation of 40kVA transformer for grid connection tests
- Extension of programmable inverters with a novel grid impedence detection method
- Development and construction of a novel modular hydrofoil micro generator
- Development and construction of two bidirectional modular DC/DC converters for battery load management
- LABView control of multi-pole synchronous machines for wind/water turbine
- Installation of a low voltage/high frequency grid emulator
- Construction and digital control of battery inverters for grid balancing

# Accomplishments

In 2016 Surena Neshvad's work in the NetPower DemoLab, funded by Luxemburg's FNR, has been awarded with the Laval Foundation Prize.





#### Adaptive short circuit protection in active grids

The evolution of the distribution network from a passive grid with unidirectional power flows to, in the presence of distributed generation (DGs), an active grid with bidirectional power flows comes along with technical challenges in its operation. On the other hand, it can also present opportunities for reinforcing control and grid support. The team's research, conducted with the FNR support and the CREOS partnership, analysed the impact of high levels of penetration of DGs into the power system on the operation of distribution network line protection.

In fact, the contribution of DGs during faults results in varying short circuit current levels that are hard to predict, complicating the design of distribution network line protection. It was shown to be solvable by direction sensitive protection parameter setting and adjustment of the DG grid code.

#### Decentral power grid parameter identification

In order to identify critical scenarios, a novel DSP method has been elaborated for the DGs Pulse Width Modulator, requesting each DG to inject a uniquely coded Pseudo-Random Binary Sequence (PRBS) along with the 50 Hz fundamental. These tasks are requested as ancillary services to the network operator. To process and evaluate the measured signals, measurements are combined and correlated in order to obtain an accurate snapshot of the power network parameters.

The real-time and online identification of grid parameters allows for dynamically controlling and fine-tuning for reliable and adapted protection.





Short circuit fault in DG dominated grid



# Cyber-Physical LV Smart Grid Environment at HES-SO



University of Applied Sciences and Arts Western Switzerland (HES-SO)

Hes.so Valais Haute Ecole Spécialisé de Suisse occidentale Fachhochschule Westschweiz University of Applied Sciences Western Switzerland

The Institute of Systems Engineering is part of the University of Applied Sciences and Arts Western Switzerland Valais (**HES-SO** Valais-Wallis). Both aim at the collaboration between economy, industry, higher education and politics and the development of new energy-related services and products. The key activities of the institute focus on energy, particularly renewable energy and smart grids, and the development of instruments for support in the field of energy, health and environment.

infrastructure.der-lab.net/hes-so



In the frame of the Swiss Competence Center for Energy Research FURIES, HES-SO has set up a cyber-physical LV smart grid environment comprising the following elements:

- a full-scale set of LV feeders forming the test smart grid, with lines emulated with discrete elements and real cables
- software controlled electronic converters connected to a force grid and to the test grid
- software components emulating the behavior of entities connected to the grid (typically smart buildings)
- an Energy Management System orchestrating flexible processes within grid connected entities, for grid control and market optimisation

This setting, based on the GridSim simulator, allows to test and assess in a full scale laboratory environment the possible contribution of grid connected entities to a smart distribution grid.

HES-SO also built a PLC test bench: A test infrastructure to measure EMC conducted disturbances and error rate on digital links has been set up. Hence interactions between EMC of DERs and other appliances, grid features, and PLC link quality can be assessed in a laboratory or operative test environment.



- Continuing education courses on operation of hydro power plants and DER installation and operation
- Testing of distribution grid control solutions
- Testing of electromagnetic interferences in smart grids
- Design of energy management systems
- Design of electronic power converters
- Consulting on interoperability of smart grid and smart metering ICT solutions

# **New capabilities**

In 2017 HES-SO plans to extend the DC microgrid test bed with a flexible EMS allowing to assess energy management scenarios.

For PLC testing, the main focus will be on the development of a PLC G3 test infrastructure.

In 2016 HES-SO set up a +/- 350 V DC microgrid with the following connected appliances:

- PV panels with individual DC/DC converter integrating MPPT functionality
- bidirectional inverters for connection to the legacy AC grid
- storage systems (Lithium-Titanate batteries)

This infrastructure is a test bed for DC microgrids with two categories of tests supported:

- electrical testing, typically voltage control and protection strategies
- energy management: optimal orchestration of storage, legacy AC grid, consumption and local generation

#### **Partnerships**

- Participation in Swiss Competence Center for Energy Research FURIES
- Consortium membership in EU projects SEMIAH and GOFLEX
- Lead of the SFOE (Swiss Federal Office of Energy) supported project REMIGATE (Reduction on electromagnetic interferences in smart grids applications: site tests and assessment)

# **Publications**

"Local algorithm for the open loop control of thermostatically controlled loads", G. Maître, D. Gabioud, and P. Roduit. Institute of Systems Engineering, HES-SO Valais-Wallis, Sion, Switzerland, IEEE ISGT 2016, Lublijana, Slovenia.

For more details please visit:

#### infrastructure.der-lab.net/hes-so



# FOSS Enhancing PV Testing and Research



University of Cyprus Research Center for Sustainable Energy (FOSS)



The **Research Centre for Sustainable Energy (FOSS)** of the University of Cyprus strives to be a regional R&I hub of excellence as well as an international state-of-the-art training and education centre. FOSS focuses its research on renewable energy sources with an emphasis on solar energy but also has expertise in energy efficiency and smart electricity grid.

infrastructure.der-lab.net/foss



In 2017-2018 the University of Cyprus (UCY) plans to transform its campus to a microgrid by installing 10MWp PV and 1MW/1MWh battery (estimated values but not optimised). The research team developed an energy management algorithm based on peak shaving. A real laboratory was required to test the algorithm for voltage limits violation at the point of common coupling (PCC) with the national grid. The test was performed at SYSLAB at the Technical University of Denmark (DTU) within the twining project TwinPV. SYSLAB offers flexible configuration of distributed energy resources (DER) and flexible control via MATLAB allowing for HIL testing. The future UCY microgrid was downscaled with a factor of 1:500 and tested with real hardware controlled via MATLAB based on the developed control algorithm.

The test was successful and showed that the developed control algorithm did not cause any voltage limits violation at the PCC.

The outcome is that a theoretical approach to the future UCY microgrid was tested with real hardware and gave the research team confidence that their theoretical work is on the right track. This will impact the successful design of the microgrid to be faster and with less problems. What is more, knowledge was exchanged between UCY and DTU, which, combined, will give a good outcome on the final design.

Testing with real hardware the algorithms developed by utilising the HIL architecture is of great value, revealing unexpected problems, such as communication delays, hardware response delays, transients due to stray components, etc.





- Professional state-of-the-art training laboratory for supporting professional and educational training programmes in the field of RES and smart grids. At present, the laboratory supports the "PV system and designer" professional training programme which is the only certified vocational training course in this field in Cyprus.
- Outdoor PV grid connected inverter testing facility comprising a PV array connected to a programmable grid-connected inverter and a high resolution dataacquisition device. Research on grid integration issues of renewables is facilitated by configuring the inverter to operate at different grid settings in order to emulate different grid conditions.
- CPV cell/module/system outdoor testing facility comprising a high pointing angle accuracy CPV tracker (< 0.1°) of 2 kWp capacity, sensors to evaluate the accuracy of the tracker, global and direct irradiance, and other meteorological sensors and a data-acquisition system. The developed apparatus facilitates research in the area of CPV characterisation and performance assessments.
- Outdoor PV module HV experimental PID testing facility comprising a HV source meter, data-acquisition meteorological sensors and a data-acquisition device. With the apparatus any PV cell/module can be tested at HV for PID, while continuously acquiring and analysing measurements of the leakage current.

In 2017 FOSS plans the following infrastructure upgrades:

- Microgrid facility to be realised in 2017-2018: The centre leads the design and implementation of the University of Cyprus microgrid, which will comprise of a 10 MWp PV park, a set of electrochemical battery systems of total capacity 1 MWh to complement the utilisation of the PV generated energy and align the electrical energy profile of the university campus to the operational needs of the system operators, thermal storage, smart controllers, meters and equipment such as heat pumps. The developed microgrid will also include an active network management unit to control the operation of the microgrid and distributed information and control units.
- Building Integrated PV (BIPV) training laboratory: The laboratory will comprise experiments in the field of BIPV that include BIPV technology characterisation, system design and optimisation. The laboratory will be designed to include remote lab functionalities.
- Indoor PV module PID testing facility: The facility will be developed in order to facilitate indoor PID tests according to the requirements set by IEC 62804. The apparatus will comprise a HV source-meter, a data-acquisition, data-acquisition system and an environmental chamber. With the apparatus any PV cell/module can be tested at HV for PID, while continuously acquiring and analysing measurements of the leakage current.

- Grid power quality measurements at designated locations of the LV grid in the scope of assessing and analysing the quality of grid in accordance to EN50160
- PV module Maximum power determination at standard test conditions (STC) according to IEC 61215 and 61646
- PV module Electroluminescence (EL) imaging, which provides a useful diagnostic technique for investigating the structural and electrical integrity of a photovoltaic device. Damaged areas of the module not visible to the naked eye can be easily pinpointed using this technique.
- PV module Measurement of nominal operating cell temperature (NOCT) of PV modules according to the requirements set by IEC 61215 and 61646. Available and fully calibrated is all necessary equipment to mount the module under test at an open-rack mounting at 45 ° inclination, with temperature sensors attached to the rear of the module along with irradiance sensors and data acquisition devices.

- PV module Thermal cycling and damp-heat tests according to IEC 61215 and 61646.
- PV system Energy yield test at the centre's three outdoor PV system testing facilities fully equipped for energy assessments of PV systems
- PV production forecasting: The centre works closely with the DSO of Cyprus in the scope of developing a PV production forecasting platform that can achieve high point and aggregated production accuracies for both hourly and day-ahead forecasts.
- Inspection of grid connected PV systems according to IEC 62446. The tests include system documentation and verification at the DC and AC side, protection insulation and energy performance.


#### **Partnerships**

FOSS joined forces with two DERlab members AIT and DTU within the twinning project TwinPV of the Horizon 2020 Twinning action programme. The programme and the project in particular aim to address networking gaps and deficiencies between research institutions of low performing Member States and internationally leading counterparts at EU level.

FOSS also has established partnerships and collaborations with Alfa Mediterranean Enterprises Ltd through an active memorandum of understanding (MoU). This collaboration supports research and innovation in the area of concentrated solar power (CSP) with thermal storage enabling the complete system to support the electricity grid since it can be dispatched according to the requirements of the energy mix.

In its role as a technical and research advisor, FOSS collaborates with EOSOLAR and is actively involved in corresponding projects. EOSOLAR is a fully licensed operator manufacturing complete CSP systems through a fully automated system with heliostats, 24 m towers with graphite tanks at the top to store the harnessed thermal energy and state-of-the-art steam engines to deliver the electric energy that operators desire to meet the active load profiles.

#### Accomplishments

In 2016 Spiros Theocharides, a student at the University of Cyprus and currently a research associate with FOSS, received an the second price *«Promoting excellence in Renewable Energy education»* from the Association of European Renewable Energy Research Centres (EUREC).



#### **Publications**

In 2016 FOSS covered a range of topics in their publications, such as:

- Advanced performance monitoring system for improved reliability and optimised levelised cost of electricity
- Thermal classification modelling and energy yield performance of different crystalline silicon photovoltaic modules with innovative packaging components
- Estimation of the degradation rate of fielded photovoltaic arrays in the presence of measurement outages



For more details please visit:

infrastructure.der-lab.net/foss

## State-of-the-Art Testbench for Research and Education at Lemcko



Lemcko - Electrotechnical Research and Power Quality Facility of Ghent University



UNIVERSITEIT GENT CAMPUS KORTRUK

**Lemcko** is the Electrotechnical Research and Power Quality Facility of Ghent University. The facility offers consultancy and troubleshooting, courses and research on three main areas: power quality, distributed generation, and energy efficiency. One of Lemcko's main objectives is to facilitate the transition from innovative academic research to real-life integration of these innovations into the LV grid by using its expertise in low frequent power quality (<2kHz), general LV electrical installations, energy efficiency and renewable energy connected to the LV distribution grid.

#### infrastructure.der-lab.net/lemcko



As a member of the INCREASE project consortium, EELAB-Lemcko contributes to the design and test procedures of a new generation of grid interactive inverters, which are capable to solve grid imbalances by adapting their yield based on a high layer control management system. The INCREASE project (INCreasing the penetration of Renewable Energy sources in the distribution grid by developing control strategies and using Ancillary Services) has the objective to develop strategies for increasing the RES hosting capacity of low- and medium-voltage networks.

Lemcko was also involved in the NEWGROW project (NEW opportunities for the LV GRid of tomorrOW) that was executed in 2016 in order to have an optimal combination between renewable technologies. The project aimed to get more insight in today's needs for reliable LV distribution networks by using PV inverters with batteries in combination with a  $\mu$ CHP unit and a PEHV (plug-in hybrid electrical vehicle), in combination with electrical and thermal storage, including the dimensioning of these elements. Also the expected performance in terms of grid stability, energy efficiency, safety and economic rentability was considered.

#### **New capabilities**

In 2016 Lemcko put into operation a new testbench for emulating wind turbines, co-generation applications and testing the electrical specifications of rotating electrical machines. A 4-quadrant regenerative drive and a specifically chosen gearbox have been deployed for simulation and testing at large power scales up to 150 kW. A speed range up to 6000 rpm and maximum torgues of 45 kNm can be applied. The advantage of emulating and analysing at high real power specifications makes it possible to explore the limits and possibilities of new developments and technologies, with the important remark that all control parameters with respect to grid and load can be manipulated.

In 2017 Lemcko will enhance the mentioned testbench for thermal analysis of electrical machines by a totally enclosed thermal chamber. Due to limited losses at higher power ratings, the accuracy of torque instrumentation needs to be especially precise for direct efficiency measurements. Consequently, the cost of measuring devices raises exponentially for high power applications. Alternatively, measuring indirect losses by thermal analysis in an insulated chamber offers more opportunities for lowcost testing of the behavior of DER and their impact on the grid.

EELAB-Lemcko engaged with an industrial partner to support the integration of CHP-systems into new markets for the customer. Besides the creation of a simulation model that could demonstrate the CHP's generator dynamical behavior, the system's LVRT must be proved under the specifications of the "Technical Guidelines for Power Generating Units and Farms" imposed by the BDEW (Bundesverband der Energieund Wasserwirtschaft). Furthermore, the simulation model had been validated by field tests on a 250 kVA machine including power set-point control, voltage and frequency control, dip and voltage fluctuation control, etc.

Besides consulting activities for high power applications, EELAB-Lemcko also serves partners in the domain of residential energy management systems and storage solutions for decreasing congestion in the low voltage grid. By giving them advice on their conceptual ideas and building first prototypes, the research staff can step by step level up their experience and bring the right solutions for upcoming challenges.

#### **Partnerships**

- TEch TRAnser project: Solutions for increasing the self consumption and self supply for SME's
- Interreg-project: towards Industry 4.0 via Networked Control Applications and Sustainable Engineering

#### Accomplishments

With respect to power quality and distributed generation aspects, Lemcko published on a range of topics in 2016:

- Assessment of harmonic emission in distribution networks: opportunity for the prevailing harmonic phase angle
- Continuous event-based harmonic impedance assessment using online measurements
- Improved event-based method for harmonic impedance assessment
- A coordinated voltage control strategy for on-load tap changing transformers with the utilisation of distributed generators

For more details and publications please visit:

#### infrastructure.der-lab.net/lemcko



## Moving Towards DC Grids at EnergyVille





EnergyVille was initiated in 2011 by two DERlab members VITO and KU Leuven as well as the research institute imec to tackle ecological and energy-related challenges and promote innovation and economic development for the Flanders region and the world. The research focus of EnergyVille is the energy transition from fossil to sustainable economy, and the development of associated technologies to enable a green energy system. The infrastructure comprises the following laboratories: control space smart grid, lighting, storage (electric: batteries & heat), hybrid drive train, thermotechnical lab and the climate room.

#### infrastructure.der-lab.net/energyville



In 2016 EnergyVille carried out BMS testing with different DC-converter topologies (half bridge topology, full bridge topology, with/without CM filter in the power stage) on supercapacitors and batteries.

EnergyVille also implemented a generic energy management strategy for controlling second-life battery systems in stationary applications with 3 batteries.

#### **New capabilities**

In 2016 EnergyVille extended their facility with:

- Bipolar DC-DC converter with two 15 kW AFE inputs and six channel outputs; maximum rating per output is 24 A and 700 V. Normal operation is +/- 700 V and 21 A per phase. At maximum flexibility, the converter can maintain a 30 kW AC connection, a +/- 700 V DC grid, one 24 A storage connection and one 24 A DC source connection simultaneously.
- Real-time simulation platform with HIL capabilities:
  - RTDS able to simulate up to 720 single phase nodes with analogue and digital component interfacing, communication and protection protocols (IEC 61850 and IEC 60870-5-104)
  - Signal amplifiers for testing up to 8 protection relays simultaneously
  - OPAL-RT able to simulate up to 300 single-phase nodes, with an optical coupling to Triphase rapidprototyping platform
  - Four-quadrant Spitzenberger & Spies 4x5kVA amplifier with a high-bandwidth for powerelectronic testing
  - SCADA interfacing with GE's PowerOn Advantage ADMS
  - Interfacing capabilities with SmartHome Lab, high voltage lab and the battery lab

In 2017 EnergyVille plans:

- Rollout of bipolar DC-grid in a TN-S configuration. The initial voltage will be +/- 400 V. The DC-grid is powered by the bipolar DC-DC converter and a 60 A/400 V bipolar DC-generator. The DC-grid has a 100 A backbone of 500 m and 4 branches of 50 m and 80 A. The grid is protected by DC circuit breakers, and protection against stray currents is provided by DC differentials. Both the circuit breakers and differentials are programmed to provide discrimination between the backbone and branches. The layout of the grid can be changed through the free choice of connection points for each branch, each source and the reconfiguration of the backbone in five 100m subdivisions.
- Demo installation for grid protection studies with a real-time digital simulator and a PHIL test bench.



EnergyVille provides consultancy on:

- inverter control and implementation for gridconnected inverters, RES inverters and storage inverters
- power system studies, with a focus on HVDC systems

#### Accomplishments

In 2016 Jef Beerten of EnergyVille/KU Leuven received the ABB Research Award in Honor of Hubertus von Gruenberg for HVDC grid studies.







University of Seville Electrical Energy Systems Group (EES-US)



The **Electrical Energy Systems Group of the University of Seville (EES-US)** carries out multiple research activities in power engineering and maintains strong connections both with the national industry and other research groups worldwide. EES-US covers a broad range of research topics, among which are energy efficiency and power quality, computational and simulation tools for power systems, renewable energy control and integration, and the contribution of distributed generation to ancillary services.

infrastructure.der-lab.net/ees-us



During 2016 the Electrical Energy System Group (ESS Group) of the University of Sevilla has been involved in research projects dealing with integration of renewable plants in power systems: CECOVEL, 3DMicroGrid, HERTZ-REN, OIPIEEM, ALLtoGATHER, RTTS and others.

#### **New capabilities**

In addition to the OPAL-RT 5600 platform, EES-US acquired two new HIL402 platforms provided by Typhoon to test innovative power electronic based controllers. Most of the lab converters are controlled with a DSP (Digital Signal Processor). The HIL platforms are becoming a standard to test new DSP algorithms before being applied to the real installation. The Typhoon HIL platform allows real-time simulations with time steps of 0.5 to 1 microsecond. This FPGA based real-time computer makes it possible to perform high precision simulations and test DSP in a highly realistic environment helping to find errors and avoiding possible damages in the real lab hardware. The capability to test several DSPs in the same HIL simulation is particularly interesting for microgrid applications. The main characteristic of these new platforms are summarised as follows: 4 cores processor,

16 analogue inputs, 16 analog outputs, 32 digital inputs, 32 digital outputs, HIL DSP interface and HIL microgrid DSP interface.

The MV scaled-down distribution system of EES-US lab was intended to analyse the impact that distributed generation may have in the distribution network. The integrated facility, based on the benchmark network proposed by the CIGRE Task Force C06.04.02, allows to test the impact of any daily load/ generation profile in a fully automated mode. During 2016 the EES-US researchers have developed a new SCADA based on RTUs provided by Vizimax improving the monitoring of the complete distribution system during the tests.



In 2017 EES-US plans to continuously improve the monitoring and control system of the MV scaled-down network by incorporating the following features:

- Monitoring system: Alarms for undervoltages, overvoltages and feeder overloading as well as dynamic symbols in the HMI to clearly show the evolution of the different electrical magnitudes.
- Control System: Including in the facility a real-time centralised • controller being able to compute active/reactive power references according to an optimisation criterion, i.e. minimisation of the total active losses of the distribution system. In this way, it should be possible to analyse in this hardware platform the influence of several implementation issues of this controller such as the influence of the delay in communications, optimal time lapse between the execution of the algorithm, etc.

In 2017 EES-US plans to finish a new facility for analysing the impact of distributed generation in LV distribution systems. The research team has reproduced a scaled-down version of the LV benchmark network proposed by the CIGRE Task Force C06.04.02. In this case, the distribution system is a three-phase four-wire network modelled with all the couplings between the phase and neutral wires. This scaled-down distribution system will also be able to be operated as an isolated system using synchronous generators, which emulate the dynamic behavior of a micro-turbine. The aim is to analyse the dynamic behavior of isolated microgrids in case of different perturbations.



scaled-down LV distribution system



General view of the scaled-down MV distribution system with the new SCADA IRI Project Vizimax 





- Optimal planning of wind farms based on the optimisation process designed by EES-US. It provides a practical way to solve in a single step all the design stages of a wind farm as the process considers the wind turbine location, internal paths, electrical installation, substation location and evacuation lines.
- Optimal operation of large-scale wind and PV farms based on an advanced solution developed by EES-US that maximises the active power production by using the adequate reactive power resources. The tool is tailored for each renewable farm and is flexible to take into account the needs of every case.
- New control strategies for wave energy developed by ESS-US with the aim of maximising the energy injected to the system
- Wide-area control using PMUs: ESS-US looks for solutions to enhance stability margins and to control oscillatory modes by adding supplementary damping devices.

- Integration of power electronic devices in distribution networks for maximising the penetration of distributed generation: ESS-US proposes to use power electronicbased converters to link radial feeders of medium voltage distribution systems to increase the penetration of distributed generators.
- Contribution of distributed generation to ancillary services: ESS-US has developed a scaled-down distribution system to test how the distributed generation can provide all these ancillary services to the utility. Impact of distributed generation, test of new local controllers, new centralised control algorithms, etc. can be tested in this scaled-down system as a previous step to an actual integration within a utility.

#### Accomplishments

#### Partnerships

The ESS-US Group established partnerships with various organisations from research, academia and industry: Red Eléctrica Española (REE), Endesa, Gas Natural Fenosa, Ingelectus, Isotrol, GPTech, Energynautics, ESDL, GeoSYS, Centre for Research and Technology-Hellas – CERTH, German-Jordanian University, Malta College of Arts, Science and Technology, KIOS Research Center within the University of Cyprus, Power System Group of Abdullah Gul University, Polytechnic National School of Oran.

During 2016 the ESS-US Group published the main outcomes of their research activities in various international journals and conferences, including such topics as:

- DC link operation in smart distribution systems with communication interruptions
- Computation of maximum loading points via the factored load flow
- Maximising the overall production of wind farms by setting the individual operating point of wind turbines

For more details please visit:

#### infrastructure.der-lab.net/ees-us





Reactive power of wind turbines before and after optimal control

## **CVVOZE Strengthening HV Capabilities**



CVVOZE Power Laboratories Brno University of Technology



**CVVOZEPowerLab** was founded as part of the Centre for Research and Utilisation of Renewable Energy (CVVOZE), a research establishment of the Faculty of Electrical Engineering and Communication at the Brno University of Technology.

The research infrastructure consists of two strategic laboratories dealing with high current and high voltage. CVVOZEPowerLab focuses on renewable energy sources including electrochemistry, electromechanics, electrotechnology, electrical power engineering, electrical drives, mobile robots and industrial electronics and also offers an open access to its RI technologies for the purposes of research, development and innovation.

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In 2016 CVVOZEPowerLab was involved in a range of activities in power system testing and co-simulation:

- 1. Simulation, design and realisation of the normal capacitor for accurate bridge measurements up to maximum voltage 200 kV.
- 2. Measurement of fast transients with usage of photometric instruments.
- Research of water bridges; electrical parameters power supply for water bridges, and measurement of electrochemical changes parameters of both water electrodes.
- Design and implementation of the digital optical detector for measurement of degradation in the liquid dielectrics, especially mineral oils.
- 5. Design and implementation of the system for measuring the electrical voltage breakdown of liquid dielectric materials with mushroom electrodes. The system allows to homogenise the liquid dielectric, allows its heating and at the same time allows to use vacuum filtration.

- 6. Research of influence of electric field on liquid insulators and their pollution at the microscopic level; microscopy of liquid dielectric materials.
- 7. Design and implementation of automatic system for heating middle and high voltage cables with galvanic separation.
- 8. Diagnostics of switching arc behavior in low-voltage systems.
- Simulations of electromagnetic and thermal fields in high-current switching devices.
- 10. Research of behavior of mechanical parts of switchgears under real short-circuit conditions.

These activities led to developing innovative design of key components of switchgears. The main innovation is more reliable numerical models and better diagnostics of switching arc phenomena.

### **New capabilities**

CVVOZEPowerLab provides capabilities for heating high and middle voltage cables with galvanic separation of the measuring circuit. Also possible in the laboratory is measurement of electrical parameters of the device with the use of the measuring bridge Tettex 2840. Furthermore, the facility provides the AC test system 300 kV 1 A with current limiter or DC output with a maximum current of 350 mA.

The capabilities of arc diagnostics were extended in high current laboratory.

In 2017 CVVOZEPowerLab plans the following infrastructure upgrades:

- 1. System of cable terminals, 350 kV AC, 750 kV LI, PD free
- SF6 normal capacitor 50 pF ± 3 %, max. 300 kV AC, PD free
- 3. Precision oil and solid dielectric analyser Tettex 2831
- 4. Test cell of liquid insultants Tettex 2903
- 5. New system for pressure field diagnostics
- 6. Qualitatively better spectroscopes for switching arc diagnostics
- 7. Far field microscope together with high-speed video for deeper diagnostics of small areas

#### Accomplishments and partnerships

#### Services

CVVOZEPowerLab provides a wide range of research services:

- Elimination of the corona and increase the breakdown voltage of middle voltage measuring resistor dividers
- Changes of electrical parameters of inductance depending on the applied voltage
- Selection of suitable solid dielectric materials based on the measurement of the dissipation loss factor and breakdown voltage
- Adjustments of bus systems in order to increase the current carrying capacity and heat transfer to the surroundings
- Consultation regarding behavior of devices under short-circuit conditions
- Arc plasma radiation
- Numerical models of physical fields in high-current devices

CVVOZEPowerLab was included into the Roadmap of Large Infrastructures for Research, Experimental Development and Innovation of the Czech Republic for 2016–2022.

CVVOZEPowerLab has established open access for researchers from universities and public research organisations. For 2016-2019 the operational costs of experiments made in open access are covered by the Ministry of Education Youth and Sports in the frame of Large Infrastructures for Research, Experimental Development and Innovations.

In 2016 CVVOZEPowerLab performed a number of studies with subsequent publishing:

- Laboratory High Voltage Capacitor with Low PD Level and Low Dissipation Factor
- Use of Photometry in the Field of High Voltage
- Effects of corona space charge polarity and liquid phase ion mobility on the shape and velocities of water jets in the spindle jet and precession modes of water electrospray
- Effective plasma radius for Planck mean absorption coefficient

For details please visit:

#### infrastructure.der-lab.net/cvvoze

#### **New equipment:**

- 1. Automatic system for heating middle and high voltage cables with galvanic separation.
- 2. Normal vacuum capacitor for accurate bridge measurements up to maximum voltage 200 kV. The research of water bridges. Electrical parameters power supply for water bridges, and measurement of electrochemical changes parameters of both water electrodes.
- 3. Current limiting water resistor (value 150 k $\Omega$ ) for the maximum operating voltage of 200 kV, with power short-term losses of 100 kW.
- 4. HV diode with a maximum transient current of 350 mA and reverse voltage of 1000 kV. The system is equipped with the resistor voltage measuring divider to a maximum voltage of 200 kV.
- 5. Handheld digital vacuum barometer GMH3161-12 for measuring of absolute pressure in the range from 0 to 1300 mbar.
- 6. DigiMicro Lab 5.0 digital microscope camera 5 MpxDiagnostics of switching arc behavior in LV systems.
- 7. Electrical water parameter HI98129 Tester for measuring of pH, TDS and EC. Research of behavior of mechanical parts of switchgears under real short-circuit conditions.
- 8. Laser system working together with high-speed video for qualitatively better switching arc diagnostics under real short-circuit conditions.
- 9. Sensitive weights for study of plastic part ablation.
- 10. Spectroscope for basic arc diagnostics.



voltage of 200 kV, with power short-term losses of 100 kW



## **TU Sofia Implementing New Research Techniques into Education**



Technical University of Sofia Research & Development Sector (TUS-RDS)



The Technical University of Sofia (TU **Sofia**) is the largest higher education engineering school in Bulgaria. It educates specialists in topics essential for the industrial development: mechanical and electrical engineering, generation, electronics, power transport, automation, computer science and telecommunications. industrial textile engineering, management.

The **Research and Development Sector (RDS)** is a unit of TU Sofia whose tasks are related to the organisation, administration and services of the research activities under contract with national research programmes and industry.

infrastructure.der-lab.net/tu\_sofia



The Research & Development Sector of the TU Sofia comprises several laboratories working in the field of smart grids, integration of renewable energy and energy efficiency.

### **New capabilities**

The new **CPCIEL laboratory** enhanced its capabilities in regards to building energy control systems:

- Improved capacity in simulation and control of domestic loads including smart building systems
- Improved capacities for combining flexible and inflexible loads
- Improved capacities for optimisation of electricity loads combining industrial and domestic ones

The **EPSSL laboratory** developed new co-simulation and physical models of PV, storage, smart load control and EV charging, and performed testing of:

- New smart load control and smart charging strategies in micro- and nanogrid operation
- New PV smart load controller for improved usage of the solar energy
- New AC smart load controller with grid support functions



The research team of the EPSSL laboratory has achieved a proof of the concept and a hardware solution for a new PV smart load controller and AC smart load controller. Improved controller settings and agent decision taking behavior have been found. The EPSSL researchers also tested and enhanced a new solution for improved usage of the solar energy in autonomous and grid connected micro- and nanogrids, as well as a new solution for AC grid supporting demand side response was tested and improved. In 2016 the **Power Electronics Supply Laboratory** (PESL) carried out research on power systems for wireless charging of EV Li-ion batteries. Flexible control of the high frequency (HF) inverter limited from resonant conditions of the flexible load with differents transmitters and differents parameters of the batteries was in the scope of the research. Another goal was to determine the level of interference generated by wireless power transfer equipment in a specific frequency range, and to compare those levels to the existing standards. The activities led to the following outcomes:

- Rapid development of the technology of wireless power transfer, especially for EV batteries charging
- The results are presented in scientific papers listed at infrastructure.der-lab.net/tu\_sofia
- Optimisation problems are defined and solved for transmitters' dimensions, bobbins' inductans and for distance from sender and receiver
- Measurement and evaluation of EMC in regards to the human exposure to electromagnetic fields
  essential aspect to guarantee occupational and general public safety

The **Power Electronics Laboratory** (PEL) performed new research activities and improved capacity for local grid simulation and testing with AC electronic load.



PEL laboratory of TU Sofia



At its laboratories the Research and Development Sector of the Technical University of Sofia provides services on the following topics:

#### EPSSL:

• Mircro- and nanogrid operation components testing

#### CPCIEL:

- Electricity consumption and power production forecasting and optimisation
- Industrial and domestic loads optimal control
- Energy monitoring and management systems incl. ISO50001

#### PEL:

• Electronic energy converters for power systems

#### Partnerships

In 2016 PESL developed partnerships with the Department of Electrical Engineering of the Faculty of Science and Technology (Universidade Nova de Lisboa, Portugal) and the Superior School of Technology of Setubal Polytechnic Institute (Lisbon, Portugal).



HIL with smart building control system

#### New capabilities and prospects

#### EPSSL:

- Configurable grid forming electronic unit
- AC Pelton turbine hydro generator capable to operate as synchronous, asynchronous and doubly fed generator
- Controllable load

#### CPCIEL:

- New programmable logic controllers for building automation installed
- Smart buildings energy models developed
- HIL structures are implemented including real control systems and building models
- IIoT implemented in the laboratory based on OPC communication

#### PEL:

• SCADA Control system for PV installation

In 2017 EPSSL aims to develop a real-time interface between the STATUS power system analysis programme and the laboratory grid forming unit.

#### CPCIEL plans in 2017:

- Improvement of building and industrial models
- Integration of PV and EV models in the HIL systems
- Integration of a laboratory with PV capacities in the HIL and IIoT systems



Pelton turbine at EPSSL



Programmable controllers, sensors and actuators at CPCIEL

PEL plans in 2017:

- Collecting and summarising data from SCADA control system for PV installation
- Improvement of inverter models for power systems



# Advances in Protection Relays Testing at TU Lodz



Lodz University of Technology



Lodz University of Technology

Lodz University of Technology (**TU** Lodz) is one of the biggest universities in Poland. The Faculty of Electrical, Electronic, Computer and Control Engineering provides different types of master and bachelor degree studies.

One of its institutes is the Institute of Electrical Power Engineering whose main research activities encompass distributed generation (including renewables) and its integration with electrical power grid, quality of supply, microgrids, optimisation of network and power plant operation, electricity markets, power system modelling and simulation as well as optimisation of lighting networks and devices.

infrastructure.der-lab.net/tu\_lodz



In 2016 the Institute of Electrical Power Engineering at TU Lodz made a strong effort in research activities related to:

- development of efficient tools based on energy storage systems (ESS) for managing operation of LV networks with distributed generation. As an outcome, novel ESS control algorithms were developed.
- testing of protection relays in closed-loop interaction of the protection system with the network model. As a result, the research team can provide support services regarding development and verification of control functions implemented in protection relays.
- V2G network ancillary services development and testing. Novel services for distributed system operators are the outcome of this activity.

#### **New capabilities**

Research activities performed at the Laboratory of Distributed Power Generation required updating and expanding the existing infrastructure. Hence, the following systems were designed and implemented:

- testbed for protection relays based on new three-phase power amplifier – Omicron CMS156, connected to Real-Time Digital Simulator (RTDS)
- PLC setup for ESS (ABB PC100) control algorithm testing
- test infrastructure based on new emulator of EV+EVSE utilising storage inverter and batteries. This system can be applied to develop, verify and test V2G ancillary services. Emulator is equipped with IEC 61850 server. The emulator's data model is compliant with TR IEC 61850-90-8

In 2017 the Laboratory of Distributed Power Generation plans to extend testing capabilities of protection relays by implementation of new test scenarios employing electrical substation ICT standard - IEC 61850 GOOSE.

It is also planned to further develop testing capabilities of e-mobility infrastructure by adding new EV charging station emulators.

Services offered by the Institute of Electrical Power Engineering include:

- HIL tests of equipment, in particular protection relays
- Interoperability evaluation of e-mobility systems
- Analysis of the operation of distributed networks with renewables and energy storage systems including:
  - impact of distributed energy sources on the power network
  - ancillary services providing by renewables and energy storages
  - impact of energy storage systems (including EV) on the supplying network
  - islanding operation of the network
- Power quality tests

#### Accomplishments

As a member of the consortium in the COTEVOS project, TU Lodz provided a significant contribution to the COTEVOS White Book "Business Opportunities and Interoperability Assessment for EV Integration" available for free download at **cotevos.eu**.

#### **Partnerships**

Institute of Electrical Power Engineering has established close cooperation with:

- PGE Capital Group one of the largest companies in the energy sector in Poland within the scope of e-mobility and energy storage systems integration
- Apator Capital Group OEM of protection systems and metering equipment - within the scope of protection systems testing and evaluation
- Lodz Branch of Polish Chamber of Civil Engineers council that groups over one hundred thousand engineers and technicians - within the scope of courses provision on renewables systems integration in distributed networks



Laboratory of Distributed Power Generation at TU Lodz

## **Cooperative Papers**

Cooperative scientific articles by DERIab e.V. (DERIab member institutes) 2016-2017 non-exhaustive list, more at der-lab.net

Title	Authors	Place of publication	Affiliation
Renewable Integration and Primary Control Reserve Demand in the Indian Power System	A. Kannan <sup>1</sup> , W. Heckmann <sup>1</sup> , D. Strauss- Mincu <sup>1+2</sup>	International Conference on Renewables, New Delhi (IN), 6-9 September 2017	<sup>1</sup> Fraunhofer IWES, <sup>2</sup> DERlab
A Software Driven Active Customer Interface for DER Integration	J. Ringelstein <sup>1</sup> , M. Shalaby <sup>2</sup> , M. Sanduleac <sup>3</sup> , L. Alacreu <sup>4</sup> , J. Martins <sup>5</sup> , V. Delgado-Gomes <sup>5</sup>	CIRED, 24th International Conference on Electricity Distribution, Glasgow, 12-15 June 2017	<sup>1</sup> <b>Fraunhofer IWES</b> , 2 <b>DERIab</b> , <sup>3</sup> Exenir, <sup>4</sup> ETRA I+D, <sup>5</sup> CTS-Uninova
Design and Evaluation of SunSpec-Compliant Smart Grid Controller with an Automated Hardware-in-the-Loop Testbed	J. Johnson <sup>1</sup> , B. Fox <sup>2</sup> , R. Ablinger <sup>3</sup> , R. Bründlinger <sup>3</sup> , J. Flicker <sup>1</sup>	India Smart Grid Week, March 2017	<sup>1</sup> <b>Sandia</b> . <sup>2</sup> SunSpec Alliance, <sup>3</sup> <b>AIT</b> .
Best Practices in Photovoltaic System Operations and Maintenance (2nd edition)	C. Whaley (working group coordinator) <sup>1</sup> , A. Walker <sup>1</sup> , T. Lowder <sup>1</sup> , C. Kurnik <sup>1</sup> , C. Nichols <sup>2</sup> , A. Qusaibaty <sup>2</sup> , D. Boff <sup>2</sup> , G. Klise <sup>3</sup> , O. Lavrova <sup>3</sup> , Roger Hill <sup>3</sup> , T. Tansy <sup>4</sup> , T. Keating <sup>4</sup> , A. Pochiraju <sup>4</sup> , J. Deot <sup>4</sup> , B. Fox <sup>4</sup>	NREL/Sandia/Sunspec Al- liance SuNLaMP PV O&M Working Group, Decem- ber 2016	<sup>1</sup> <b>NREL</b> . <sup>2</sup> US DOE SunShot Initiative. <sup>3</sup> <b>Sandia.</b> <sup>4</sup> SunSpec Alliance.
Enhanced Situational Awareness and Decision Support for Operators of Future Distributed Power Network Architectures	A. S. Zaher <sup>1</sup> , V. M. Catterson <sup>1</sup> , M. H. Syed <sup>1</sup> , S. D. J. McArthur <sup>1</sup> , G. M. Burt <sup>1</sup> , M. Chen <sup>1</sup> , M. Marinelli <sup>2</sup> , A. Prostejovsky <sup>2</sup>	EEE ISGT Europe, Ljubljana (SI), October 2016	<sup>1</sup> University of Strathclyde. <sup>2</sup> DTU.
Evaluation of System- Integrated Smart Grid Devices Using Software- and Hardware- in-the-Loop	B. Lundstrom <sup>1</sup> , S. Chakraborty <sup>1</sup> , G. Lauss <sup>2</sup> ,R. Bründlinger <sup>2</sup> , R. Conklin <sup>3</sup>	Conference on Innovative Smart Grid Technologies (ISGT2016) by IEEE, Minneapolis, MN (US), 6-9 September 2016	<sup>1</sup> <b>NREL.</b> <sup>2</sup> <b>AIT.</b> <sup>3</sup> US Department of Energy.
Towards a Foundation for Holistic Power System Validation and Testing	M. Blank <sup>1</sup> , S. Lehnhoff <sup>1</sup> , K. Heussen <sup>2</sup> , D. E. Morales Bondy <sup>2</sup> , C. Moyo <sup>3</sup> , T. Strasser <sup>3</sup>	IEEE ETFA, Berlin (DE), 6-9 September 2016	<sup>1</sup> OFFIS. <sup>2</sup> <b>DTU.</b> <sup>3</sup> <b>AIT.</b>
Towards Holistic Power Distribution System Validation	T. Strasser <sup>1</sup> , F. Andren <sup>1</sup> , G. Lauss <sup>1</sup> , R. Bründlinger <sup>1</sup> , H. Brunner <sup>1</sup> , C. Moyo <sup>1</sup>	CIGRE, Paris (FR), 21-26 August 2016	¹ <b>AIT.</b> ²OFFIS. ³TU Delft. <b>⁴NTUA. ⁵IWES</b> .
and Testing – An Overview	C. Seitl <sup>1</sup> , S. Rohjans <sup>2</sup> , S. Lehnhoff <sup>2</sup> , P. Palensky <sup>3</sup> , P. Kotsamonoullos <sup>4</sup> , N.		<sup>6</sup> DNV GL. <sup>7</sup> RSE. <sup>8</sup> DTU <sup>9</sup> University of
Possibilities	Hatziargyriou <sup>4</sup> , G. Arnold <sup>5</sup> , W. Heckmann <sup>5</sup> , E.C.W. de Jong <sup>6</sup> , M. Verga <sup>7</sup> , G. Franchioni <sup>7</sup>		Strathclyde. <sup>10</sup> DERlab. <sup>11</sup> TECNALIA.
	L. Martini <sup>7</sup> , A.M. Kosek <sup>8</sup> , O. Gehrke <sup>8</sup> , H. Bindner <sup>8</sup> , F. Coffele <sup>9</sup> , G. Burt <sup>9</sup> , M. Calin <sup>10</sup> , L.F. Bodriguez-Seco <sup>11</sup>		

Title	Authors	Place of publication	Affiliation
Stochastic Model Predictive Control for Economic/ Environmental Operation Management of Microgrids: An Experimental Case Study	A. Parisio <sup>1</sup> , E. Rikos <sup>2</sup> , L. Glielmo <sup>3</sup>	Journal of Process Con- trol 43, July 2016, pp.24–37	<sup>1</sup> <b>University of</b> <b>Manchester</b> . <sup>2</sup> <b>CRES</b> . <sup>3</sup> University of Sannio.
Forecasting and Observability: Critical Technologies for System Operations with High PV Penetration	PJ. Alet <sup>1</sup> , V. Efthymiou <sup>2</sup> , G. Graditt <sup>3</sup> , N. Henze <sup>4</sup> , M. Juel <sup>5</sup> , D. Moser <sup>6</sup> , M. Pierro <sup>6</sup> , F. Nemac <sup>7</sup> , E. Rikos <sup>8</sup> , S. Tselepis <sup>8</sup> , G. Yang <sup>9</sup>	EU PVSEC2016, Munich (DE), 20-24 June 2016	<sup>1</sup> CSEM, PV-center. <b><sup>2</sup>FOSS</b> . <sup>3</sup> ENEA. <b><sup>4</sup>IWES</b> . <sup>5</sup> SINTEF. <sup>6</sup> EURAC. <sup>7</sup> ApE. <b><sup>8</sup>CRES</b> . <sup>9</sup> TU Denmark.
Experimental Validation of Flexibility Provision by Highly Distributed Demand Portfolio	M. H. Syed <sup>1</sup> , G. M. Burt <sup>1</sup> , R. D'Hulst <sup>2</sup> , J. Verbeeck <sup>2</sup>	CIRED Workshop, Helsinki (FI), June 2016	<sup>1</sup> University of Strathclyde. <sup>2</sup> EnergyVille-VITO.
Transitioning from Centralised to Distributed Control: using SGAM to Support a Collaborative Development of Web of Cells Architecture for Real-Time Control	E. Guillo-Sansano <sup>1</sup> , M. H. Syed <sup>1</sup> , P. Dambrauskas <sup>1</sup> , M. Chen <sup>1</sup> , G. M. Burt <sup>1</sup> , S. McArthur <sup>1</sup> , T. Strasser <sup>2</sup>	CIRED Workshop, Helsinki (FI), June 2016	<sup>1</sup> University of Strathclyde. <sup>2</sup> AIT.
Report on the Sizing of Primary Control Reserve Capacity for the Indian Synchronous System and Secondary Control Reserve Capacity Exemplified for Rajasthan	D. Jost <sup>1</sup> , S. Bofinger <sup>1</sup> , A. Kannan <sup>1</sup> , D. Strauss-Mincu <sup>1+2</sup>	GIZ - India Green Energy Corridors, June 2016	<sup>1</sup> Fraunhofer IWES, <sup>2</sup> DERlab
EMC Issues in the Interaction between Smart Meters and Power Electronic Interfaces	P.Kotsampopoulos <sup>1</sup> , A.Rigas <sup>1</sup> , J.Kirchhof <sup>2</sup> , G.Messinis <sup>1</sup> , A.Dimeas <sup>1</sup> , N.Hatziargyriou <sup>1</sup> , V.Rogakos <sup>3</sup> , K.Andreadis <sup>3</sup>	IEEE Transactions on Power Delivery, vol. 32, Issue: 2, April 2017, pp. 822-831	1 <b>ntua</b> . 2 <b>iwes</b> . 3Hedno.
Distribution Line Parameter Estimation Under Consideration of Measurement Tolerances	A. Prostejovsky <sup>1</sup> , O. Gehrke <sup>1</sup> , A. Kosek <sup>1</sup> , H. Bindner <sup>1</sup> , T. Strasser <sup>2</sup>	IEEE Transactions on Industrial Informatics, vol.12, no.2, February 2016, pp. 726-735	1 <b>DTU</b> . 2 <b>AIT</b> .

## **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 investigations and testing
- Network protection
- Electric vehicles



#### DERlab e. V. Board

From left to right:

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#### Activity Report 2016 / 2017

published by

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Kassel, August 2017

Pictures on the cover: DTU DNV GL TNO NREL (photo by Dennis Schroeder) Sandia National Laboratories University of Luxembourg Authors: representatives of DERlab member institutes; DERlab Office

Editorial Team, Coordination: Maria Sosnina, Dr. Diana Strauss-Mincu

Layout: Marvin Herbring, Maria Sosnina





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