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PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	IGDySMoV
User-Project Title	Island Grid Dynamic Stability Model Verification
Main-scientific field	Smart Power Grid Stability
Specific-Discipline	Dynamic stability analysis of pure inverter controlled island grids

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Position in Organization	Professor

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

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Activity type and legal status* of Organization	1
Position in Organization	PhD Student

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

(Repeat for all Users)

Date of submission	26. January 2012
Re-submission	NO
Proposed Host TA Facility	Fraunhofer IWES, Kassel
Starting date (proposed)	February / March / April 2012

Summary of proposed research (about ½ page)

Prepare a ½ page summary describing the relevance and the scope of the proposed work, and the expected outcome(s)

This lab investigation is part of a PhD project, which is investigating the stability of pure inverter driven island grids. The stability and dynamics analysis is based on a control model of the island grid and this control model shall be validated in a real laboratory setup before pursuing further analysis.

A dynamic control model of an island power grid, purely generated by voltage source inverters, without rotating - and thus stabilising - generators has been developed. Without rotating masses, the grid dynamics depend purely on the fast inverter logic, which is not bound to slow, physical, energy-based time constants.

The elaborated control model will serve as foundation for investigations of the necessary boundary conditions for a stable and reliable operation of highly parallelized off-grid inverters in micro grids or power island grids. The main research objective is to provide a safe approximation of the stability of inverter driven power grids and to engineer a new grid for maximum stability.

The intended laboratory setup will particularly verify the assumed model linearisations. Several setups of grid structures with a number of programmable inverters shall be interconnected as a grid. Depending on the grid structure, the line impedance (resistive/inductive) and inverter droop control parameters, the power flows and transients will be observed at the grid nodes and the measurements will be compared to the model predictions and numeric simulations.

One particular aspect of the developed model concerns the propagation of frequency changes throughout the grid. The Kuramoto model predicts the frequency changes and synchronisation of physically coupled oscillators, based on non-linear differential equations and has been used for stability analysis in traditional power grids with rotating generators [FD10]. The applicability of a modified Kuramoto-like model to an inverter driven power grid shall be verified in a laboratory setup.

State-of-the-Art (about 1 ½ page)

Describe in brief (in about 1½ pages) the current knowledge on the subject, citing recent relevant references. Identify any knowledge gaps and their relevance.

A lot of research is conducted on how off-grid inverters can be controlled efficiently, which type of control algorithms can be applied and if a certain control methodology can guarantee a necessary level of grid parameter quality, e.g. [DGI04], [Kim09].
There are investigations about using high voltage droop control, where the grid has a rather reactive/inductive characteristic, also for low voltage grids, where the grid has a rather active/resistive characteristic, e.g. [Kuh07, Kuh09].
There are also extensive research results available about large scale interconnected generator-grids, investigating parameter control, protection against short circuits or power surges, or grid stability, e.g. [Dil95].
In contrast to investigations on large scale interconnected generator grid stability, none however has questioned the stability and reliability of a large scale interconnected inverter grids, which are on the threshold of being applied in the smart grid and industrial applications. The innovation in this thesis is to not only regard one inverter and its capability to rule out grid parameter deviations, but to regard the whole grid stability as the counter actions of each inverter influence all other inverters in the grid.
While slowly controlled inverters react slowly and thus possess a certain inertia, high speed controlled inverters react with a high dynamic. The reaction of one inverter to rule out a parameter deviation will trigger reactions on other inverters before the grid reaches its equilibrium state.
Investigating the behavior of the <u>complete grid model</u> as a whole will allow to judge the stability of such structures independently of the exact component behavior, as long as the components behave along a specified parameter vector.

The expected extensive use of parallel off-grid inverter installations in the future, demanded by higher energy efficiency and lower pollution emissions, strongly requires a concise model to engineer reliable structures.
Potential instabilities have already been predicted 1995 by Tuttas [Tut95] and have finally been reported by Meyer in 1999 [MM99 , PM98] in the Swiss railway grid, where break energy reinjection into the grid via inverters in combination with resonance poles led to several grid blackouts.
Basis of this work is the VSI model of Engler [Eng99, Eng01, Eng05] who investigated at ISET in Kassel, Germany (now Fraunhofer IWES) the general feasibility of generating and maintaining power grids only with droop based voltage source inverters.
Osika [Osi05] started an investigation of power grid stability based on Engler's model, but remained with a multi-inverter system where all inverters have one common point of coupling. Distributed grids were not investigated.
Sachau reaches in [Sac05] the conclusion, that a multi VSI system remains stable, when the overall inverter time constant remains proportional to its rated power.
Based on the state space model of a VSI, Ritwik et.al [RM10] investigate the power distribution between several inverters and propose an angle droop control instead of a frequency droop control for improved power balancing.
Different aspects of inverter fed power grids are illuminated, however, none of these recent investigations analyses the grid model as a whole with regard to the influence of the grid structure itself on the grid stability and the necessary boundary conditions for a safe operation.

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Kuh07 Walter Kühn. Systemdienstleistungen unter besondererBberücksichtigung von Wechselrichtereinspeisungen - anhang 6. VDE-Studie Dezentrale Energieversorgung 2020 1, VDE, May 2007.
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Tut94 Christian Tuttas. Beschreibung von u-Pulswechselrichtern durch Netzwerke aus Multiplizierern und Addierern. Archiv für Elektrotechnik, 77:367–374, 1994.
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Eng01 Alfred Engler. Regelung von Batteriestromrichtern in modu- laren und erweiterbaren Inselnetzen. PhD thesis, Universität Gesamthochschule Kassel, May 2001.
Eng05 Alfred Engler. Applicability of droops in low voltage grids. DER Journal, (1), January 2005.
Osi05 Oleg Osika. Stability of MicroGrids with High Share of Inverter- dominated and Decentralised Sources. Phd thesis, University of Kassel, 2005.
Sac05 Jürgen Sachau. Reduced pole placement method for cas- caded frequency control via dispersed pulse inverters. Eu- ropean Transactions on Electrical Power, 15:343–350, February

2005.
RM10 Arindam Ghosh Ritwik Majumber, Balarko Chaudhuri. Im- provement of stability and load sharing in an autonomous microgrid using supplementary droop control. IEEE Tran- sactions on Power Systems, 25(2):796–808, May 2010.
FD10 Florian Dörfler, Francesco B.: Synchronization and Tran- sient Stability in Power Networks and Non-Uniform Kura- moto Oscillators. In: American Control Conference (2010), S. 930–937

Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest (2-3 pages)

Provide a detailed description of the objectives of the proposed activity, the way these objectives will be fulfilled through the proposed work, as well as indications on the expected outcome and the fundamental scientific and technical value and interest of the proposal. Specify the type of TA infrastructure (distributed generation simulator; domotic house; etc.) and the test setup. With the understanding that these aspects will be discussed with the TA infrastructure after approval of the proposal and specified in the Agreement to be signed between the TA infrastructure and the User team, indicate the number of tests to be carried out and their sequence, the response quantities to be measured through the instrumentation, etc. Describe any special requirements for equipment, standards, safety measures, etc. Point out any shortcomings, uncertainties and risks for the fulfillment of the project objectives, as well as the means to mitigate relevant risks.

The linear control model, developed by M.Jostock who will perform all experiments, generally allows to describe and analyse arbitrary grid structures. For the laboratory experiments a set of simple grid structures has been identified.

Before (and during) the experimental phase simulations are prepared with expected results. These simulated results will be compared to the laboratory experimental results for verification of the linearised control model.

The model is based on voltage source inverters, operating with droop control f(P) and u(Q), adjusting their output frequency according to the provided active power and adjusting their output voltage according to the provided reactive power. The fact that this type of inverter control can lead to equally shared load distribution of multiple VSI in an island grid has already been proved by Engler [Eng01] at IWES. The VSI control should be implemented in each inverter according to illustration 1.

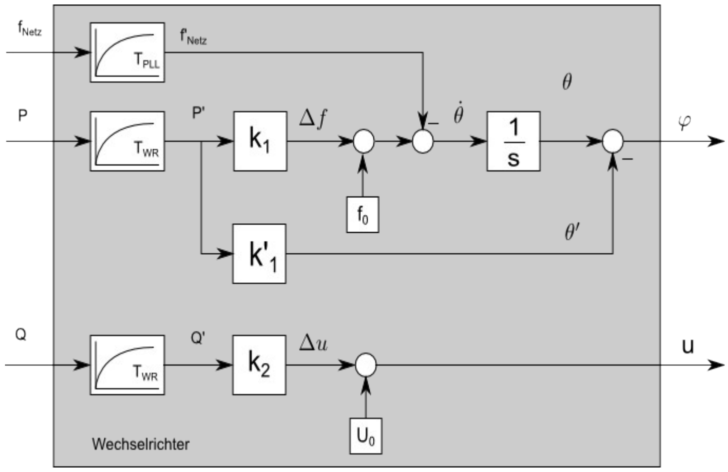


Abbildung 1: Inverter Control Model

Parameters are: T_{PLL} – Time constant of the PLL, T_{WR} – real or imposed time constant of power measurement and power controller, k_1 – frequency droop, k_2 – voltage droop, k_1' – frequency dampening

Based on the proposed inverter control model, two blocks of experiments are prepared:

A) Verification of the linearised control model of an inverter driven power grid

B) Verification of a modified Kuramoto-like model of frequency change and angle propagation through an inverter driven power grid.

Block A – Linearised Model Verification

A linearised control model has been developed, based on the equations of power flow accross one branch with conductance G and susceptance G from node 1 to node 2:

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} -B & G \\ -G & -B \end{bmatrix} \cdot \begin{bmatrix} u_1 u_2 sin(\varphi_1 - \varphi_2) \\ u_1^2 - u_1 u_2 cos(\varphi_1 - \varphi_2) \end{bmatrix}.$$

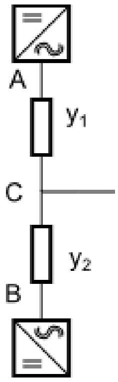
In order to be able to perform pole-zero analysis and Lyapunov stability analysis on arbitrary grid structures, this non-linear equation has been approximated by a small signal model for small phase and voltage differences by

$$\begin{bmatrix} P \\ Q \end{bmatrix} \approx \begin{bmatrix} -B & G \\ -G & -B \end{bmatrix} \cdot \begin{bmatrix} \varphi_i - \varphi_j \\ u_i - u_j \end{bmatrix}.$$

Based on the grid's node incidence matrix, the control model allows to calculate the active and reactive power flow over each network branch and voltage and phase in each network node. For an arbitrarily large grid it enables the aforementioned network stability analysis.

For a stable operation of two voltage source inverters it is important, that they equally share the load of the whole network, based on their implemented droop control.

Experiment Setup A.1: Simple Line Network with two VSI



Two VSI (A & B) are feeding one common load, each VSI connected via a different line impedance ($y_1 \neq y_2$) to a common point C, where an active and reactive load is connected.

For this first simple structure of two VSI, simulation results have been obtained for the reaction of the VSI on a load surge of P=0.8p.u. and Q=0.2p.u.,displayed in illustration 2.

Illustration 2 shows that the inverter dynamics lead to power oscillating effects for the active power which may lead to unstable modes. The reactive power is not equally distributed, essentially meaning that one VSI is providing reactive power to the other VSI.

The experiments are inteded to verify or falsify these effects.

Variations of the experiment execution include changes of the VSI control parameters k_1, k_2, k_1', T_{PLL}, T_{WR} in order to analyse their influence on the system stability.

Variations of the line impedances y_1 and y_2 are necessary to investigate the ohmic situation in a low voltage grid and the rather ohmic-inductive situation in a medium voltage grid.

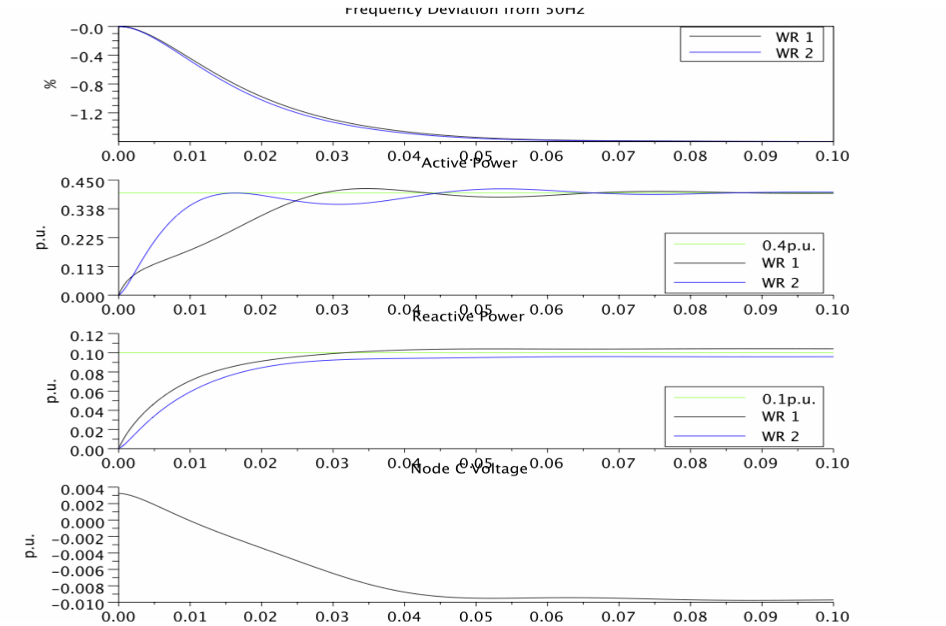
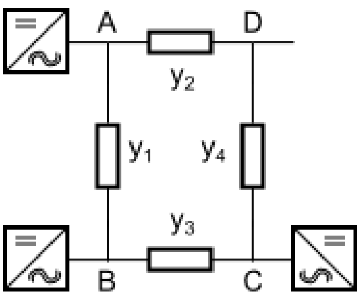


Abbildung 2: Simulation Result for Simple Line for Experiment Setup 1

Experiment Setup A.2: Basic Mesh Network with 3 VSI



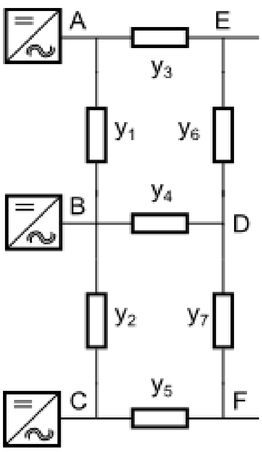
A network with one mesh of interconnected VSI, coupled by the line impedances will be set up.

The influence of the mesh structure on a load surge at node D is to be observed and to be compared to the grid simulation.

Again, the VSI are expected to equally share the load after a transient phase. VSI at node B is expected to contribute at slowest rate due to the increased line impedance.

As in experiment setup 1, variations of the execution include changes of the VSI control parameters k_1, k_2, k_1', T_{PLL}, T_{WR} of each VSI. Variations of the line impedances y_1 to y_4 are necessary to investigate the different situations of low voltage grids and medium voltage grids.

Experiment Setup A.3: Complex Meshed Network



A complex network with two meshes, three VSI and two nodes with connected loads will be set up.

Three VSI feed power into a more complex network of two meshes, where power is drawn at the two nodes E and F. This is the first step towards a arbitrarily complex network structure to be analysed.

Simulations of grid behavior need to be compared to the experimental results, based, as in setup 1 and 2, on the variations of the control parameters of the VSI and the line impedances in order to cover the low voltage and the medium voltage range.

Block B – Kuramoto-like Frequency Propagation

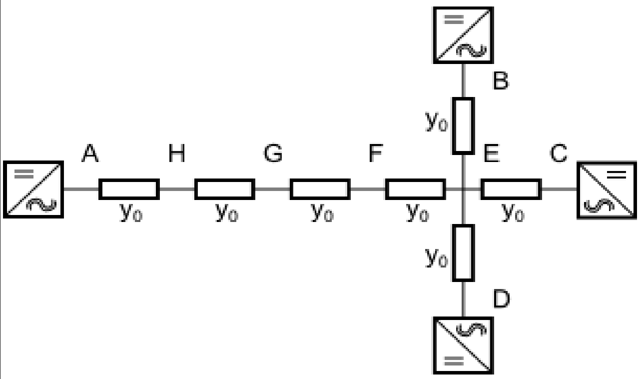
When one VSI is changing its frequency at which it injects power into the grid, e.g. due to a spacially close load surge, its phase will drift with respect to the phases of the other VSI in the system. While superposition of sinusoidal signals with different frequencies and phases is a highly non-linear problem, Yoshiki Kuramoto found the differential equations which describe the problem and predict the synchronisation of phase and frequency. His model has been applied to power systems with rotating generators, where the physicall rotor masses compose the oscillators [FD10].

A modified Kuramoto-like model has been assumed in the development of the linearised control model for the inverter driven power grid:

$$\dot{\vec{\theta}} = -\mathcal{K}\mathcal{Y}\mathcal{K}^{\mathsf{T}}\sin(\vec{\theta})$$

with the node incidence matrix K, the diagonal admittance matrix Y and the vector of the node phasors θ. This aspect is to be verified in the following experiments.

Experiment Setup B.1: Frequency Change at one Point



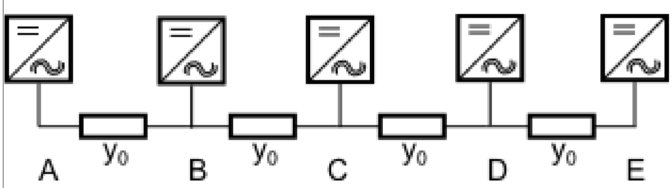
The proposed setup will be used to investigate the frequencies, measured by the PLLs of the VSI in the nodes B,C and D upon a frequency change of the VSI in node A.

The frequency change can either be programmed directly in the VSI A, or be forced by a load surge in node A.

It is intended to measure and prove the dependency of the PLL reactions in B,C,D on the impedance between the nodes A and E. The impedance of the connection A-E can be variegated either by chaining standard blocks of y_0, or by a variable impedance, if such an equipment will be available in the laboratory.

For this purpose it is important to have access to the PLL output frequency of each VSI.

Experiment Setup B.2: Frequency Change Propagation



In this setup, all VSI operate as in Block A with f(P) droop and u(Q) droop.

A load surge in node A will provoke a frequency change in the closest connected VSI. This frequency change will propagate throught the network and initiate a transient phase of power fluctuations.

The main point of this experiment is, that during the transient phase after the load surge, there is no common grid frequency, but each VSI will measure its own local frequency, until the load sharing is settled and all VSI reach the same new, stable grid frequency. The dynamics of the frequency propagation, certainly depending on the time constant of the PLL, are an important factor for the control model and the overall grid stability.

Required TA infrastructure:

As can be seen in the description above, the TA infrastructure should provide:

- At least three, but rather five, programmable voltage source inverters (VSI).
  The VSI must at least be able to operate in a f(P) droop and U(Q) droop. Preferably they are freely programmable with arbitrary control algrithms which permit to implement a desired behavior with adjustable droop for frequency and voltage. Ideally several parameters should be accessible for analysis, e.g. the current PLL frequency.
  The rated power is of lower importance. Three phase VSI would be preferable.
- Resistances and inductances to set up line connections between the VSI with typical values for low voltage and medium voltage lines. Fixed value impedance blocks are good, freely configurable impedances would be better.
- Measurement equipment, particularly for active and reactive power as well as phasor measurements, at different nodes of the grid. Measurements should be captured by a data storage system and timing of different measurement nodes must be synchronisable for correct analysis and evaluation.

Originality and Innovation of proposed research – Broader Impact (1-2 pages)

Demonstrate the originality and innovation of the proposed work and the impact the expected results will have on current and future research or practice, public safety, European standardization, competitiveness, integration and cohesion and on sustainable growth.

The direct output of this investigation will be

- a set of formal models for high speed off-grid inverter dynamics and a set of parameters which allow to classify inverters with regard to their influence on the grid stability
- a mathematical description of a grid composed of n parallel inverters allowing to perform grid stability analysis by changing the equivalent circuit of the power bus or by adapting the inverter parameters
- laboratory results as verification of the developed linearised inverter driven grid model for stability analysis

In the mid term, the results of this project serve as a base for further investigations of specific types of grids or inverters. E.g. depending on the voltage level (high voltage or low voltage), the grid power bus behaves rather inductive or rather ohmic and thus the stability can be influenced. The model found in this project allows to adapt the stability analysis to the specific grid model or inverter characteristics.

Particularly the linearised model allows the fast analysis of large scale inverter driven grids. The insights on the relations between grid structure and grid stability will allow to base future stability analysis on the composition of larger grids from smaller grid components like lines, loops and trees. Knowing the general dynamic behavior of the inverters within a range of pre-defined boundary conditions will allow to judge grid stability and overall behavior of the grid dynamics in an efficient and fast manner.

Further it will allow to develop software tools for computer aided design (CAD) of grid analysis where a pre- fabricated component library of inverters are used. CAD and CAM tools for electrical engineering can be extended to facilitate the design of islanding part-grids and of independent grids, e.g. railway grids.In case of technical problems in existing grids, the model could serve as base for improved error diagnostics and limitation of error sources.

In the currently evolving smart grid technologies, and the increasing complexity of the power grid structure, as more small sized distributed sources inject energy into the power grid, simplified and fast tools and approaches are needed in order to judge the dynamics and stability of a specific grid struchture, without the necessity to be in possession of the exact dynamic models of each component, as manufacturers will not necessarily want to share these models. As long as the equipment manufacturers and utilities can guarantee that their assets are operating in a specific parameter range or if device specifications are published as ranges – without compromising the producer's legitimate interest of protection of intellectual property – the grid analysis will still be possible, due to the outcomes of this research project.

In the long term, as more and more large scale inverter grids are built up, the stability analysis should be come a feasible standard procedure during the construction phase for dynamic reliability.

The construction and planning will be simplified and as the wide spread use of inverters, constructed at favorable costs, will lead to increased energy efficiency and the reduction of environmental emissions.

This will lead to manageable island grids e.g. for communities and large buildings providing energy autonomy since a large number of diversified energy sources can be incorporated by simple energy injection into the existing grid.

Synergy with ongoing research (about ½ page)

Provide information on any concurrent research project with the same or similar subject with the one proposed. Describe the synergy (if any) that will be sought between the existing and the proposed project.

As mentioned, this laboratory experimental phase is part of a PhD thesis and the results will be of direct relevance to the investigations of boundary conditions for a reliable and efficient control of energy systems formed by highly parallelized off-grid inverters.

The experimental results will be directly incorporated into the thesis as they serve as a basis for the validation of the elaborated dynamic control model of the inverter driven island grid.

Particularly the practical experience in experimental setups are beneficial not only to the lab user, but also for the subsequent application in the Netpower Demolab at the University of Luxembourg, which has been associated to the DERlab network in 2011. Specially the exchange of practical and experimental knowledge between the different DERlab institutions will foster the synergic effects of the acquainted knowledge to be exchanged with other team members of the Netpower Demolab in Luxembourg, who are currently working together in the FNR-financed project *Reliable and Efficient Distributed Electricity Generation in Smart Grids.*

As the Netpower Demolab in Luxembourg is currently in its ramp-up phase, particularly the hands on experimental knowledge, can further be exploited and applied.

Dissemination – Exploitation of results (about ½ page)

Describe the means through which the results to be obtained from the proposed project will be diffused and made broadly known.

The laboratory experimental phase is part of a PhD thesis and the results will be of direct relevance to the investigations of boundary conditions for a reliable and efficient control of energy systems formed by highly parallelized off-grid inverters. The PhD thesis will probably be published by end of 2013. The thesis will be available in public library services and there are no limitations or restrictions on the publications.

Intermediate results will already be published in international transactions or conference papers. Particularly after the laboratory verification a publication is foreseen of the elaborated and then verified control model of the inverter driven power grid for discussion in the international science community.

Possible publication journals are e.g. European Transactions on Electrical Power, IEEE

Transactions on Control System Technology, IEEE Transactions on Smart Grids or IEEE Transaction on Parallel and Distributed Systems.

Direct dissemination benefits will be available through the Netpower Demolab team members in Luxembourg, as the experimental and practical knowledge gained at the DERri institution will be applied at the Netpower Demolab and shared with the local team.

The PhD project is co-tutored by the University of Kaiserslautern, Germany, where M.Jostock regularly participates in PhD student sessions and presentations. The experimental results will be presented in Kaiserslautern as part of these sessions and the perpetual project presentations.

Time schedule (about ½ page)

Provide an indicative time-schedule for the proposed work and a target starting date.

The schedule for the described lab setup and experimental phase is intended to take **four weeks**.

- Week 1
    - lab introduction, acquaintance of security instructions
    - training on lab equipment, hardware and measurement utilities
    - experiment setup A.1
- Week 2
    - experiment setup A.1 (continued)
    - experment setup A.2
    - possibly experiment setup A.3
- Week 3
    - experiment setup A.3
    - experiment setup B.1
    - possibly experiment setup B.2
- Week 4
    - experiment setup B.2
    - time buffer for experiments A.1-A3, B1
    - wrap up and presentation of results

Description of the proposing team (as long as needed)

Give a short description of each member (organization and persons) of the proposing team including publications, experience in test campaigns and role in the proposed project.

Prof. Jürgen Sachau

Following his studies in Electrical Engineering - computer and control engineering - at TU Braunschweig with Prof. Werner Leonhard, J. Sachau received his PhD on control of independent power grids. From 1984-1989 he was project leader for decentral energy systems at the University of Kassel and from 1989-1995 he joined the german energy research institute ISET as founder and head of the systems engineering department, also founding the programme preparation.

He is a cofounder of the EUREC-Agency of sustainable energy research institutes and companies. At DG Research in Brussels, he was appointed sector leader, from 1995-1997 leading three clusters of non-nuclear energy projects in four EC-programmes and finally became responsible for supply quality monitoring and information technology of EU-funded sustainable power systems at the EU's joint research centre JRC, Ispra. Lecturing since 1992, he was appointed professor at the Energy Institute of the University of Kassel in 2000 and in 2003 founded the Systems and Control Engineering Chair of the University of Luxemburg where he participates in the Interdisciplinary Center for Security, Reliablity and Trust.

He is the founding editor of the International Journal of Sustainable Energy and is currently editor of the European Transactions on Electrical Power.

Dr. Florin CAPITANESCU

F. Capitanescu worked as a research engineer at the University of Liege (Belgium). He graduated in Electrical Power Engineering from the University Politehnica of Bucharest (Romania) in 1997. He obtained the Ph.D. degree in Applied Sciences from the University of Liege in 2003. His main research interests lie in the field of power systems planning, operation and control. His research is particularly focussed on applications of optimization methods (LP, NLP, MILP, MINLP, MPEC) in the field of power systems, in particular (security-constrained) optimal power flow, and voltage stability. His doctoral thesis was entitled. “Preventive assessment and enhancement of power system voltage stability: an integrated approach of thermal and voltage security”.

Florin contributes the project “Reliable and Efficient Distributed Electricity Generation in Smart Grids” in the team of Prof. J. Sachau.

Dipl.Ing. Markus Jostock

During his studies of Electrical Engineering at the University of Kaiserslautern, Germany, M. Jostock was already engaged in industrial development with control algorithms for medical laser applications. After obtaining his diploma, in 2000 he joined Agilent Technologies (now Verigy), a spin-off of Hewlett-Packard, as R&D engineer in the semiconductor test department for the development of test algorithms for large scale System-on-a-Chip testers used for high speed semiconductor tests. In 2005 he joined Software AG in Luxembourg and worked for several years in European projects in the control of large scale distributed multi-agent systems, intensifying his knowledge and experience in dynamic system control, automation and parallel systems.

In 2010 M. Jostock joined the University of Luxembourg as PhD Candidate with an FNR grant for the investigation of boundary conditions for a stable and reliable operation of highly parallelized off-grid inverters in micro grids and power island grids under the supervision of Prof. J. Sachau.

The control model he developed for the analysis of inverter driven power grids is subject of the proposed laboratory experiments and the experiments will be performed by M.Jostock.

Ilya Bilibin, MSc.

I. Bilibin completed a Master in Applied Mathematics and Physics at the Moscow Institute of Physics and Technology, (State University). His research interests are Modelling of complex systems, Power systems reliability and efficiency, and Smart grids.

From 2009 until now Bilibin was Lead specialist in the Forecasting and Analysis Dept of a non-profit partnership which manages the wholesale Russian electricity and power capacity market where he achieved advanced knowledge of the Russian energy system and participated in the development of the Russian power capacity market.

In 2011 I. Bilibin joined the University of Luxembourg as PhD candidate and is working on the CORE project REDESG “Reliable and Efficient Distributed Electricity Generation in Smart Grids” under the supervision of Prof. Jürgen Sachau.

Netpower Demolab

The Intedisciplinary Centre for Security, Reliability and Trust (SnT) at the University of Luxembourg operates the NetPower DemoLab in a strong and motivated research environment. In the team led by Prof-Dr.Ing. Jürgen Sachau.

Elaborated are PhD topics like :

- Reliability and Vulnerability of Electricity Networks
- Multimodel Control Design for Reliable Poleconstellations
- Reliable Distributed Costoptimal Dispatching in Smartgrids
- Stability Verification of Nonlinear Automata Dynamics for Modular Solar Energy Systems
- Reliable State and Parameter Observation for Electrochemical Storage Units

The NetPower DemoLab intends to provide a test bed infrastructure in order to easily set up scenarios under investigation, based on a wide range of technologies, particularly in the emerging smart grid technologies, including industrial production grids.

The main focus is on the system perspective of the interaction between communication infrastructure and the power infrastructure and the resulting security and reliability.

The NetPower Demolab structure for embedding constructive solutions in the computer aided engineering process is combining real and virtual testbeds progressing from offline to online testing. For both hardware in the loop and software in the loop testbeds, realtime simulations up to Mhz scanrates are employed to engineer failproof signal processing and constructive solutions, e.g. in power electronics, in their systems context.

The NetPower DemoLab equipment covers realtime 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 realtime fieldbus protocols, thus allowing for safety, security and reliablity testruns of networked SCADA systems in realtime in complex virtual environment and failure scenarios.The Netpower DemoLab investigates communication structures and power grid structures and different aspects of security and reliability.

The Netpower Demolab is part of the education for Electrical Engineering and Informatics Bachelors and Master of Communicative Systems. **The Netpower Demolab is associated with the European network of excellence DERlab** for mobility of researchers and European projects.