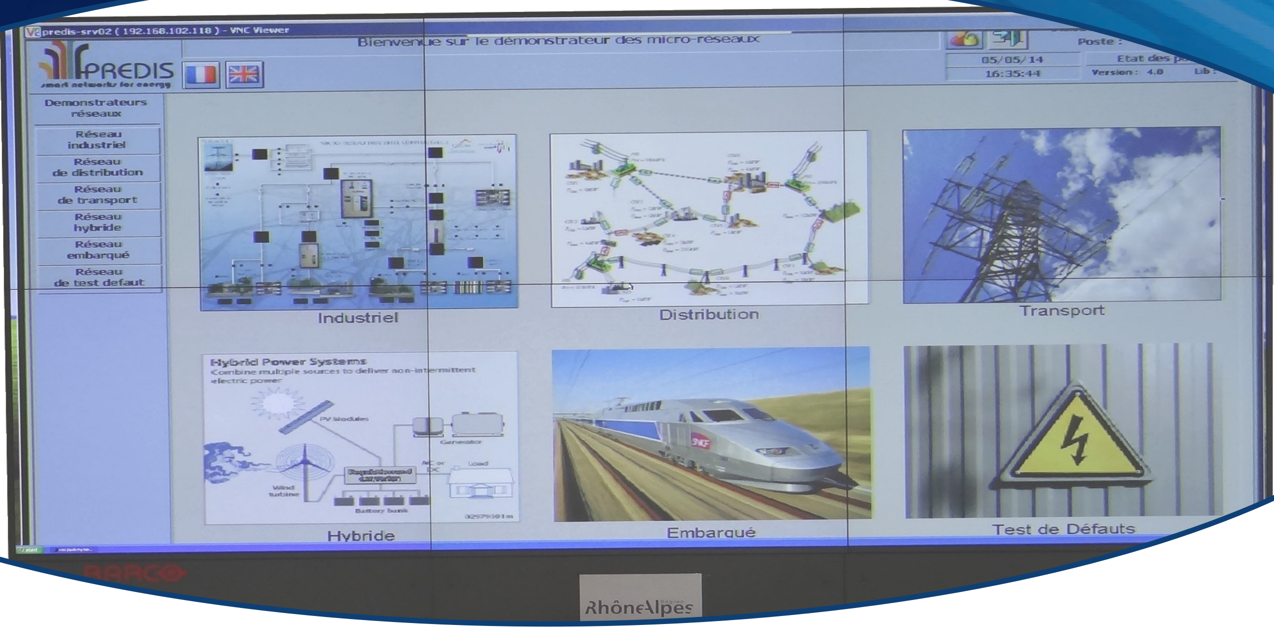
G2E lab
Grenoble Génie Electrique
Grenoble Electrical Engineering

Energy efficiency oriented

Highlights 2014



Systems and Electrical Networks

Grenoble INP
Université Joseph Fourier GRENOBLE
cnrs
lanef
INSTITUT CARNOT Energies du futur

Foreword

SYREL: Systems and Electrical Networks

The SYREL team (power networks team) focuses on the development , optimization and control of electrical systems , it means systems of production, transmission and use of energy power whatsoever at the buildings, data centers, embedded, distribution and transmission networks. A feature of the team is to conduct both work upstream and downstream in a research strongly linked to industrial applications and large projects and demonstrators at the national level. SYREL is the most important team in France for research in electrical engineering dealing with electrical systems and networks.

In the current socio-economic context, the electrical energy is a key element of sustainable development and smart grids. The production, transmission and distribution of this clean energy are subject to new techno-economic constraints to meet the quality requirements and availability.

The core research of the team are the intelligent networks in their broadest sense, « smart grids «, site networks, embedded networks : a global problem that can be handled from component to macro system. Electrical networks are complex systems, which many elements are in strong interaction. The interdependence of electrical systems, information systems and communication systems is one of the concerns in conjunction with the industry. These interactions are subject to the constraints of production and consumption that make the grid a dynamic system and one must maintain its stability despite very different temporal dynamics (lightning surge , mechanical stability , voltage collapse , production planning , investment decisions , deteriorating quality). The researches have a highly multidisciplinary aspect (economics, automatic control , electromagnetic , mechanical, hydraulic, ...) and are linked to many stochastic phenomena.

It is within this major societal issue that represent energy and the environmental concerns than SYREL team develops tools for the study, modeling and optimization of this complex system. Network planning and taking into account the constraints and developments on the horizon of 30-40 years are being investigated in connection with planners and distributors. The system Production / Transmission / Generation is therefore a complex infrastructure, requiring substantial investment in a context of strong evolution: we will therefore endeavor to develop tools to optimize the structure and control while maintaining the quality and availability. The availability and quality of electric power are mandatory, it is necessary to add to the system protection functions, self-healing and preventive diagnostic functions that require information. Measured data or expertise, local or centralized, this information must go through the now inseparable networks of power transmission communication systems.

The three structural axes research team are:

- *Unconventional connected systems*
- *Analysis and optimization of advanced power systems*
- *Advanced methods in understanding and securing complex infrastructures*

Contents

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DREAM European project

Distributed Renewable resources Exploitation in electric grids through Advanced heterarchical Management

Launched in September 2013, the DREAM collaborative project (2013-2016) is merging 12 academic and industrial partners from 7 European countries. Sustained up to 3.750.000 EUR by the European Seventh Research Framework Program (FP7), the project is led by Raphaël Caire from G2Elab - Grenoble Institute of Technology.

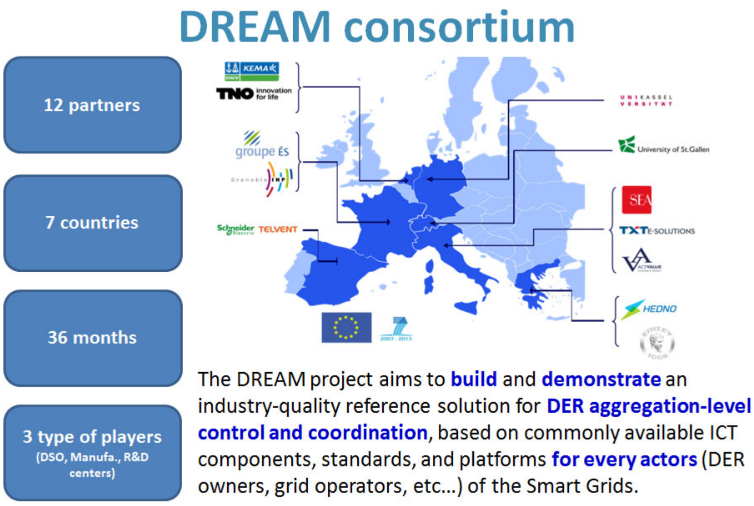
The promising project will lay the foundations for a novel heterarchical management approach of complex electrical power grids, providing new mechanisms for stable and cost effective integration of distributed renewable energy sources, as well as for enhanced consumer involvement in economic and ecological electricity use.

Applying the principles of autonomous agent-based systems to the control and management of the electricity distribution grid will allow the system to constantly adjust to current operational conditions and make it robust to exogenous disturbances. In turn, this will allow for greater penetration of intermittent resources and will make the distribution grid more resilient to failures. DREAM will include several layers of controls for normal, congested and post-fault situations that will use different coordination strategies ranging from market-based transactions to emergency demand response and create ad-hoc federations of agents that will flexibly adjust their hierarchy to current needs. The system will transit smoothly between control layers depending on local operational conditions, so that responses to disturbances will be sized precisely, margins will be used parsimoniously and full network flexibility will be tapped. The system will involve only limited data transfers and no centralized control, promoting extensibility, heterogeneity and easy deployment across countries with different network architectures and hardware manufacturers allowing Distribution System Operator to optimize its assets and to enhance the flexibility of distributed resources to best integrated renewable sources.

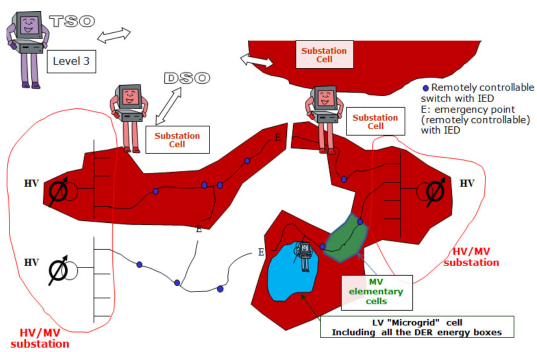
DREAM will demonstrate the economic and technical feasibility of these novel control mechanisms thanks to several real-world small-scale pilots dedicated to different use-cases, and computer simulations will be used to study further scalability.

Furthermore, economic viability will be modelled and examined for the various actors in the grid taking into account the unpredictability of consumer power production, market dynamics, novel regulation schemes and the adoption of DREAM mechanisms over time.

The project also includes the dissemination of the results to a wide community.



The DREAM project aims to **build** and **demonstrate** an industry-quality reference solution for **DER aggregation-level control and coordination**, based on commonly available ICT components, standards, and platforms **for every actors** (DER owners, grid operators, etc...) of the Smart Grids.



Scenario to be validated: energy/balancing markets

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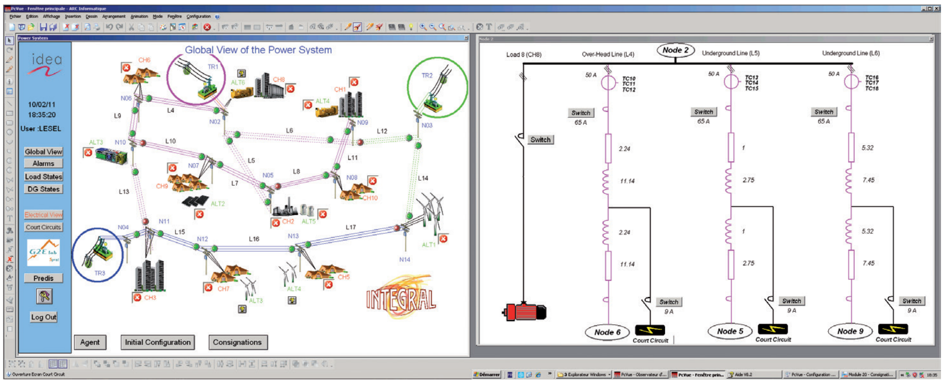
FURTHER READING
http://www.dream-smartgrid.eu/

INTEGRAL European project

Integrated ICT-Platform Based Distributed Control (IIDC)

INTEGRAL



Synoptic distribution network RD PREDIS (PCVue®)

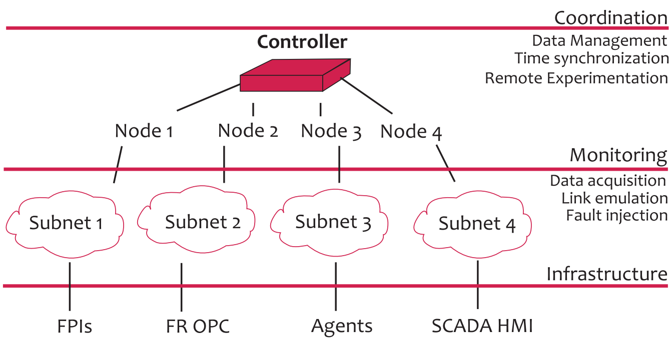
Front panel fault record (FR)

INTEGRAL - Integrated ICT-platform based Distributed Control (IIDC) in electricity grids with a large share of Distributed Energy Resources and Renewable Energy Sources In line with the European projects FP5 CRISP (LEG and IDEA were then partners) and MICROGRID, the previous partners had decided to add value to the existing concepts. The idea was to demonstrate the contribution of new information and communication technologies (NICT) and, more particularly, of distributed intelligence, to help control distribution networks which include a high rate of distributed generation. The project kicked off on 1st November 2007. After two years spent perfecting the advanced function algorithms (management by intelligent agents) the demonstrator phase began on three sites:

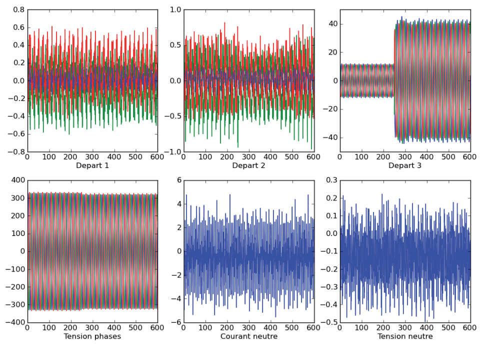
- Demonstrator A, located in the Netherlands (Groningen), proves the capacity of local agents to add value to renewable energy on the energy markets and to electricity network operators (local system services such as management of congestion or voltage profile).
- Demonstrator B, located in Spain (Girona), proves the capacity of intelligent agents associated with a self-sufficient zone to provide support before a general failure (blackout).
- Demonstrator C, situated in France (Grenoble), proves the contribution of local agents to helping with the automatic recovery of distribution networks following a fault.

All of these agents, thanks to «bottom-up» actions, must be evaluated in terms of calculation capacity and telecommunications requirements.

This evaluation will make it possible to specify an ICT infrastructure which is shared between the various stakeholders in the distribution network.



Analysis of data in transit in areas

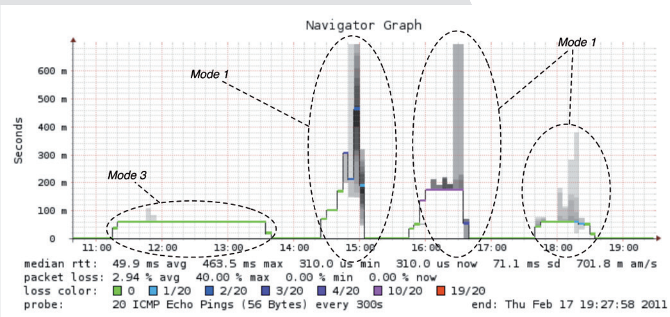


Example of recording default on departure 3

More ...

Partners

- Grenoble INP (FR), leading university in the field of energy
- Energy Research Centre of the Netherlands (NL) ECN, equivalent of the French CEA
- IDEA EIG (FR), economic interest grouping between EDF, Schneider and Grenoble INP
- Blekinge Institute of Technology (SE) BTH, a Swedish university specialising in information systems for energy infrastructures
- KEMA which bought out Gasunie Engineering and Technology (NL) GET, the R&D centre of the Dutch gas distributor
- WattPic (SP), start-up specialising in intelligent distributed systems and solar trackers
- CRIC (ES), specialising in communicating on-board systems
- NTUA (GR), Greek university specialising in autonomous systems and their distributed management
- EnerSearch (SE) EnS, a company created from the Free University of Amsterdam
- Humiq (NL), which bought out ICT, a company specialising in information system solutions



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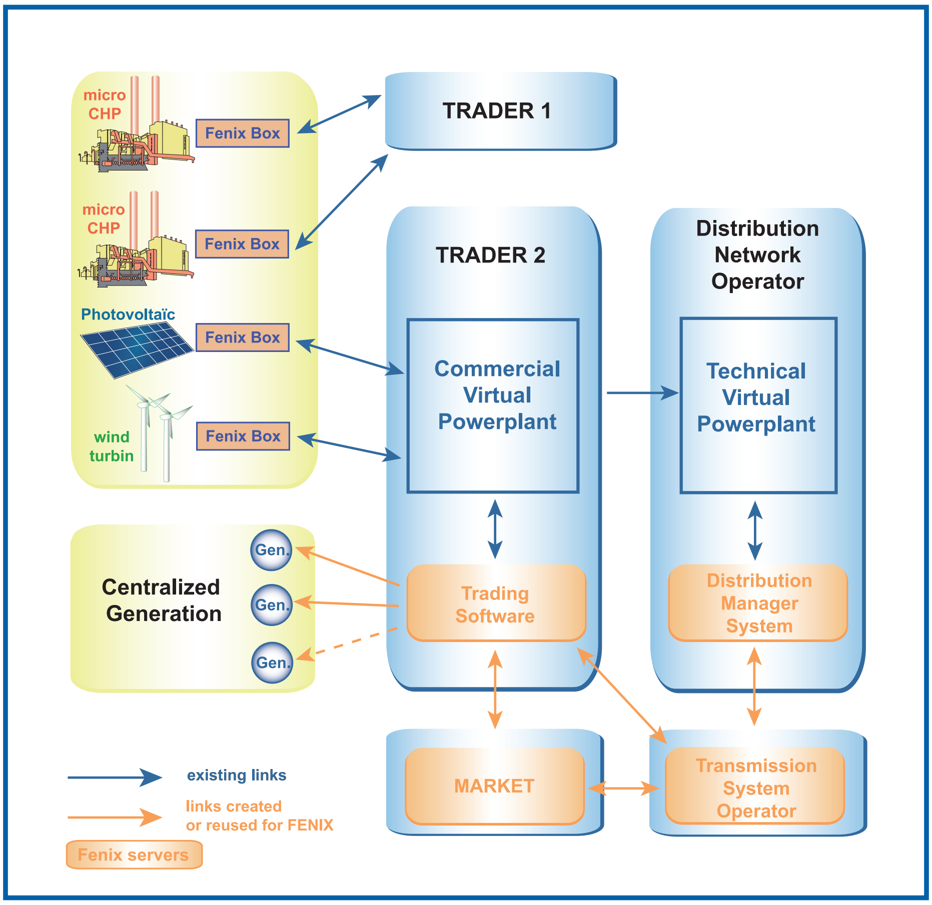
Fenix European contrat

fenix
'...a step towards the future of electricity network'



Fenix principle

Motivated by the wide diversity of challenges, large transmission network managers, distribution network managers, manufacturers and research establishments in Europe have formed a consortium of 18 partners grouped together under the name of FENIX. This consortium aims to conceptualise, design and test a technical architecture and a commercial framework which would allow systems based on DEGs to be used as the solution for an effective, safe and renewable European electricity network.

Fenix's key concept is the virtual power plant or aggregated power plant: a representation of a set of distributed small producers by means of an equivalent with behaviour similar to that of a traditional power plant. This concept can be broken down into two very different scenarios:

- The commercial virtual power plant, which is a driving force for producers achieving optimal recognition on the energy markets.
- The technical virtual power plant is a new function of the distributor which makes it easier to manage network congestion by means of an ad hoc aggregation. The power stations which TVPP applies to are the ones connected to the same distribution pocket.

The interactions between these new stakeholders and the traditional stakeholders in the electricity system are specified in the diagram.

More ...

Partners
Areva T&D Energy Management Europe, ECRO SRL Romania, EDF Energy Networks UK, Electricité de France, Energy Research Centre of the Netherlands, Fundación Labein Spain, Gamesa Spain, Groupment pour inventer la distribution électrique de l´avenir-IDEA-France, Iberdrola SA Spain, Imperial College London UK, Institut für Solare Energieversorgungstechnik Verein an der Universität Kassel e.V. ,ISETGermany, Korona Inzeniring DD - Slovenia, National Grid Transco UK, Poyry Consulting Ltd UK, Red Eléctrica de España SA, REE Spain, ScalAgent Distributed Technologies France SIEMENS AG, Austria, The University of Manchester UK, Vrije universiteit Amsterdam, VUA Netherlands , ZIV PmasC SL Spain

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Further reading
http://www.fenix-project.org/

1st global vision demonstrator of the SmartGrid

GreenLys

An ambitious challenge

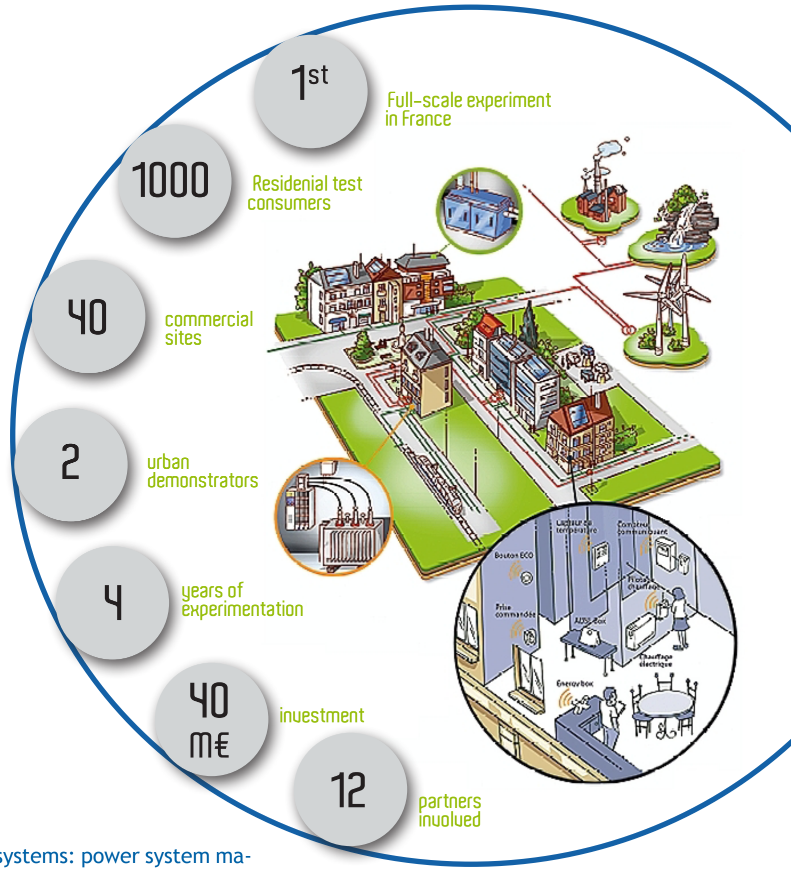
GreenLys is an ambitious project selected by ADEME as part of the first investment programme for the future. The GreenLys territory: the experimental districts of Grenoble and Lyon.
Its scope: the entire electricity network, from producer to consumer, including transportation, distribution and supply. Its aim: to implement the first full-scale Smart Grid demonstrator incorporating the widest range of advanced consumer services and grid control functions. A complete demonstrator, capable of validating a costbenefit analysis of a Smart Grid in real-time operation, controlling future investment needs or even performing behavioural studies of newly empowered users, the consumers.

Helping consumers save on energy

- by installing innovative equipment on consumer premises that is connected via the Internet to a platform of services and guiding consumers on how to use these new tools,
- by testing new prices and services with participants in the pilot project,
- by giving consumers personalised advice to help them control their energy costs,
- by conducting new sociological studies in order to better understand consumer behaviour and acceptance.

A complete urban demonstrator offering the first global smart grid vision

Producers, transporters, distributors, energy suppliers, manufacturers, private and public research laboratories and associations have come together to conduct the first full-scale experiment in an urban area with 1,000 residential consumers and 40 commercial sites on two experimental platforms in Grenoble and Lyon. The aim of the project is to develop a technological showcase ready for widespread deployment by 2016.



Defining the control methods for the smart power grid

- to improve the performance and agility of the grid thanks to advanced control functions, planning tools, real-time communication of the grid status and «self-healing» functions,
- to incorporate new decentralised electricity production sources such as photovoltaic cells and cogeneration on a much wider scale and demonstrate the convergence between natural gas and electricity,
- to incorporate renewable energies and new uses of electricity locally for global benefit,
- to manage new uses of electric vehicles (recharging, storage, etc.),
- to find greater flexibility in energy management by developing the aggregator function,
- to take advantage of Linky smart meters to encourage the emergence of new offers and services for grid users.

In GreenLys, the G2Elab will contribute through its expertise in electrical systems: power system management, architecture and algorithm optimization, grid reliability and economic viability of energy. Further contributions include grid operation management with distributed generation, building energy management, and electric vehicle integration on the grid. Preliminary demonstration will be carried out using a simulation tool developed by the G2Elab: the SMART GRID PREDIS platform.

More ...

Partners
- ERDF, GEG - Distribution System Operators
- GDF-SUEZ - Energy provider
- Schneider Electric, electrical solutions provider
- Grenoble INP, Grenoble Institute of Technology

and experts in the SmartGrid domaine :
Atos Worldgrid, CNRS-LEPII, HESPUL, CEA-LITEN, ALSTOM GRID, RAEE and RTE

Financial partner
- French Environment and Energy Management Agency (ADEME)

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Further reading

http://www.greenlys.fr/

ESPRIT project

ESPRIT

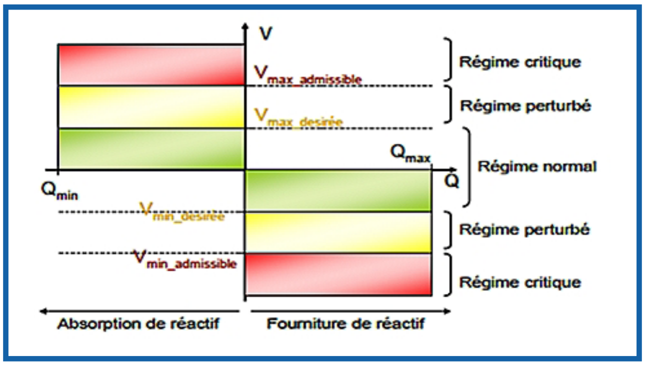
The objective of the ESPRIT project was to define a regulatory and technical framework in France which would guarantee an adequate level of operation of PV installations on a network for electricity producers and distribution network managers.

The first task involved the dissemination of documents looking at the state of the art (bibliographical summary, translation of standard DIN VDE 0126, inverter topologies, islanding detection), which highlighted several regulatory or technical recommendations for an optimised connection of inverters to the network.

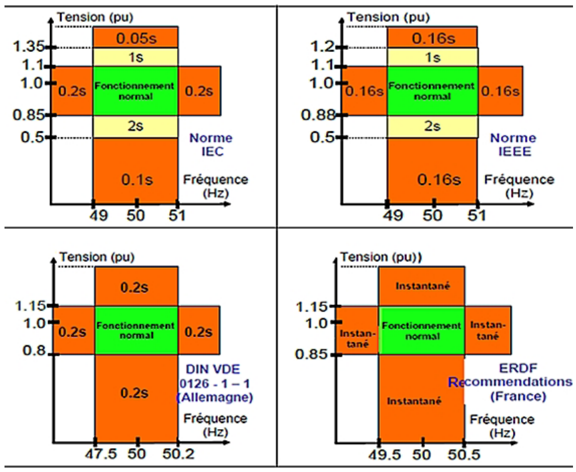
The project also involved the installation of monitoring equipment on three sites in France which presented operational problems. The measurement data could only partly confirm these facts and proposals were made to operators in order to further the research or resolve the detected problems.

In parallel, and as part of the second task, monitoring data was analysed and highlighted, as various behaviour of the PV systems or phenomena had remained almost undetected until that point (reactive exchanges between the PV systems and the distribution network, current peaks during inverter start-ups or shut-downs and inverter stalls, etc.).
This behaviour was analysed by means of digital simulation and modelling. An evaluation of the robustness of islanding detection by measuring impedance in various scenarios; these simulations allowed us to highlight the fact that these methods contributed to the increase in harmonic rates in the electricity networks, but, above all, in certain very special cases they could cause the unjustified disconnection of inverters or fail to acknowledge each other, thereby meaning that a genuine islanding situation may not have be detected. This was all the more the case as the number of inverters increased.

Task 3, which aimed to define the services that the systems could contribute to the network, showed through simulations the real contribution that an intelligent control system in inverters could make to their dynamic adaptation to the network characteristics (particularly compliance with the voltage plan); to the resistance to disruption occurring on the network in order to eliminate inadvertent disconnections; and to the filtering of current harmonics in order to improve the voltage signal quality in the network.



Auto-adaptive regulator settings



IEC, IEEE DIN VDE 0126 and ERDF settings for anti islanding protections in low voltage networks

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More ...

Partners

- HESPUL - not-for-profit organisation specialized in Rational Use of Energy and Renewable Energy Saving promotion through technical, educational and social activities
- CEA INES – Research center dedicated in Solar Energy
- EDF R&D – Resaarch center of EDF
- G2Elab
- IDEA – Joint research center of Schneider Electric, EDF R&D and Grenoble-INP
- TRANSENERGIE - consulting firm specializing in renewable energy (RE), Energy Efficiency (EE) and Demand Side Management (DSM).

Further reading

Transformerless inverters and RCD : What's the problem? »,T. Tran-Quoc, H. Colin, C. Duvauchelle, B. Gaiddon, C. Kieny, LE Thi Minh, S. Bacha, S. issanou, . Moine, Y. Tanguy, proceedings of the 25th European Photovoltaic Solar Energy Conference and Exhibition, p4555-4559, Valencia, 2010

« Couplage Onduleurs Photovoltaïques et Réseau - aspects contrôle/commande et rejets de perturbations », Le Thi Minh Chau, PhD thesis, 25/01/2012

G3-PLC for distribution network operation

SOGRID

Le réseau électrique de demain

SOGRID is collaboration project with global ambitions led by ERDF and STMicroelectronics in a consortium of 10 partners which has been officially launched on April 11, 2013 in Toulouse. The project is the result of the call for projects from ADEME (French Environment and Energy Management Agency) aiming to develop smart grids.

This experimentation is part of a global approach to develop smart grids (smart electric networks), in particular a complete communication chain across electricity distribution networks.

The project will develop a next-generation chip that aims to power millions of devices connected to the mains and allow them to communicate with each other and constitute a smart grid.
Through SOGRID, the partners of the consortium ambition to define an international communication standard around the concerning power line communication (PLC) protocol, contributing to the construction of an industrial sector of excellence in France.

In SOGRID, the G2Elab will contribute to:

- the development of an innovative sensor network: by developing prototypes of advanced MEMS (MicroElectroMechanical Systems) sensors and proposing solutions for the synchronization of measurement systems using GPS technology to increase the potential of the solutions proposed by industrial partners;
- the development of new algorithmic solutions using new performances of electronic components and innovative sensors: by developing methods to using measurements from the sensors to reconstruct the state of the electrical network and algorithms used to assist energy management operators according to the specifications of distribution network;
- a laboratory pre-demonstration of the energy management solutions developed in the project by providing access to its PREDIS-smart grid experimental platform;
- the dissemination of project results in the scientific community.

More ...

Partners
- ERDF – Distribution System Operator
- STMicroelectronics - Electronics and semiconductor manufacturer
- Nexans – Copper and fibre optics cable manufacturer
- Sagemcom – Telecommunication solutions provider
- Landis+Gyr – Smart meter manufacturer
- CapGemini – IT consulting services
- Trialog – Consulting company, PLC expertise
- Grenoble INP - Grenoble Institute of Technology
- LAN – Numerical Applications Laboratory
- Ecole Polytechnique – Paris Institute of Technology

Financial partner
- French Environment and Energy Management Agency (ADEME)

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FURTHER READING

http://www.so-grid.com/

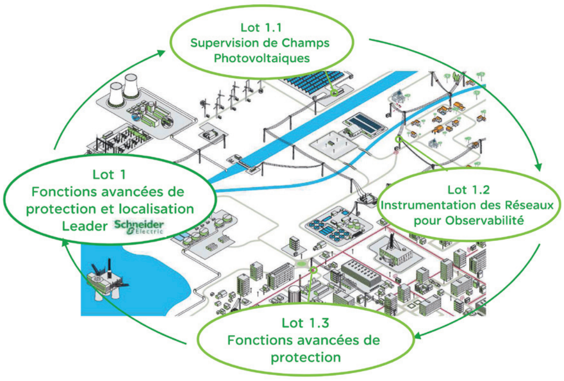
Reflex project

The project kicked off in December 2005, shortly after the establishment of the TENERRDIS competitive cluster looking at the theme of Network Management.

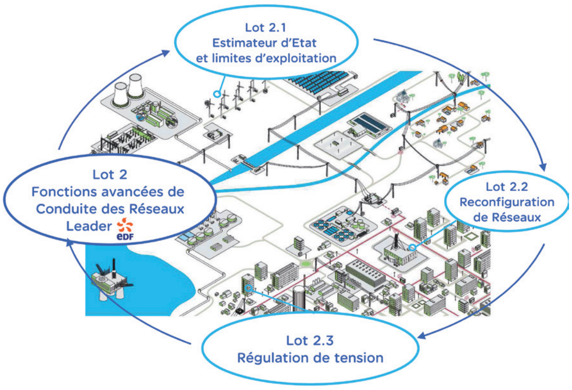
The theme of flexible networks has already been examined in several research projects within IDEA because innovation for flexible networks is very closely linked to progress in the field of information and communication technologies. One day soon, distribution networks will have to address two objectives:Maintaining a quality of service which meets the expectations of their customers and optimising their costs (operational and investment), while integrating strong development of distributed generation and energy demand management (EDM), with variations depending on local circumstances. Developing local means of generation will reveal new operational issues, particularly for voltage control or the operation of protection devices. Although the main network infrastructure will probably remain quite stable, the operating mode will have to evolve. Starting from a pre-existing infrastructure, the networks of the future will have to become more flexible and adaptable. They will be able to integrate, in particular, automatic self-healing capabilities in the event of a fault, but also capacities to control distributed generation used for load management techniques (communicating metering, load control, etc.) in order to be able to more effectively manage peak demand.

The development of new information and communication technologies is an opportunity to rise to this challenge and improve the performance of these infrastructures. However, this modernisation calls for sustained multidisciplinary research efforts. Since the life cycle of network investments is long (over 30 years), companies in the sector are trying to anticipate and optimise these changes in their investment plans.

In 2010, the REFLEX project produced many successes. The demonstrators put in place by industrial partners (photovoltaic field supervisor, sensors in communicating fault passage indicators/networks, protection system integrating fault distance functionality, test model for advanced control functions) enchanted financiers at the various review meetings. The objectives concerning patents, publications and a positive impact on turnover and local employment are all within reach. The project made full use of the synergy created by IDEA, which was ahead of its time in the flexible networks field.



Reflex works part 1



Reflex works part 2

More ...

Partners

- Schneider Electric
- EDF
- G2Elab
- ScalAgent

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Superconducting Fault Current Limiter for meshed HVDC grids

Meshed High Voltage Direct Current (HVDC) grids are foreseen as an economical, suitable and very efficient solution for the transfers of large amount renewable energies through submarine cables or/and on long distances: offshore wind generation farms and desert solar energies. Nevertheless this attractive technology faces the technical hurdle of managing fault currents. In DC it is no more possible to take advantage of the AC current zero-crossing in order to clear a fault. Whereas it is possible to fix this issue in today point-to-point HVDC transmissions by interrupting the current on the AC sides, it becomes a difficult task and significant lock in meshed HVDC grids. The control of the voltage converters does not allow handling the fault currents due to the diodes connected anti-parallel across the controlled switches. The estimations of the fault currents in meshed HVDC grids overstep the switching and clearing capacity of the state of the art DC circuit breaker and destroy the diodes of the converter.

This very annoying problem could be solved by using Superconducting Fault Current limiters (SCFCL) whose first medium voltage devices are installed in grids. G2Elab has long experience and know-how on SCFCL design and grid integration. Recently it participated to the Eccoflow EU project (figure 1), one of the most ambitious project worldwide on Superconducting technologies applications. The SCFCL is based on the intrinsic highly non linear voltage versus current characteristic of a superconducting element. Under a given DC current the voltage across it is nearly undetectable making it invisible for the grid. On the other hand, as soon as a current oversteps this given current a high voltage develops itself automatically and naturally, which limits the fault current amplitude without any external action.

A circuit breaker is required to isolate the superconductor and avoid its damaging. The superconducting length can be favourably used to show an inductance to limit the fault current rise. In DC systems, this superconducting inductance does not introduce any voltage drop in normal and steady state operation.

Investigations have been carried out at G2Elab in the context of the Twenties EU project. Through a suitable design of SFCL it is possible to limit the fault currents in the diodes to two times their rated current thus avoiding any damage to them. The simulations take into account the propagation, the cable model versus the frequency and a very accurate model of the components (IGBT) of the converter with its control. Figure 2 shows the meshed HVDC grids with the SFCL. In figure 3 we can see that the SFCL really limits the fault current which can be interrupted within 4 ms after the short-circuit considering a 15 kA breaker. The SFCL has also a very positive effect on the current rise in the diodes by slowing it down: the diode current reaches 2 p.u. after 2.16 ms without SFCL but 4.95 ms with an optimized SFCL (Figure 3). With this delay a DC breaker with a clearing capability of 15 kA meets the requirements for the diodes since it opens within 4 ms (Figure 3). In this HVDC example the SFCL represents the only possible solution to cope with fault currents with the today state of the art of the DC breakers.

Figure 1 : Eccoflow 24 kV – 1 kA SCFCL to which G2Elab participated

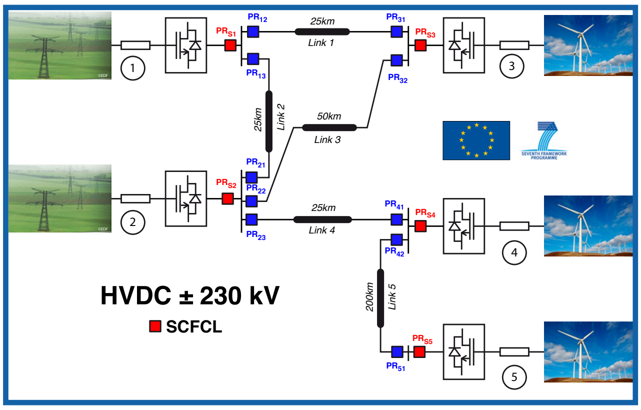

Figure 2 : Studied HVDC grid for wind farm connexions (Twenties EC project)

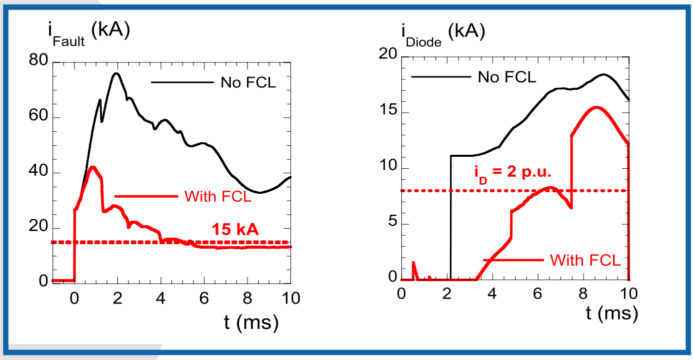

Figure 3 : Line and diode fault currents versus time with and without SFCL for a fault.

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Further reading

Innovative distribution networks planning integrating superconducting fault current limiters
C. Gandioli, M.-C. Alvarez Hérault, P. Tixador, N. Hadjsaid, D. M. Rojas Medina
IEEE Transactions on Applied Superconductivity vol 23 pp5603904

Design and production of Eccoflow Resistive Fault Current Limiter
A. Hobl, W. Goldacker, B. Dutoit, L. Martini, A. Petermann, P. Tixador
IEEE Transactions on Applied Superconductivity vol 23 pp 5601804

Protection system for meshed HVDC network using superconducting fault current limiters
J. Descloux, C. Gandioli, B. Raison, N. Hadjsaid, P. Tixador
IEEE grenoble powerTech 2013

Realtime power hardware in the loop simulation facility

The first hybrid real-time simulator with ARENE URT associated to real power devices has been implanted in G2ELab in 2002. The thesis work of Christopher Gombert allowed to run power electronics models with real PWM controllers. Wind power systems has been emulated by machine and connected to Real Time Grid simulators interfaced by a linear three phase amplifier. The physical chain consists on back to back voltage source inverters, Double Fed Asynchronous Machine, Emulated turbine. The thesis of Dan Ocnasu and Haizea Gaztañaga continued this effort with another premiere regarding the coupling of real DFACTS series and shunt associated to a simulated wind farm.
Many other works have been continued with the theses of Erwan Lepelleter, Octavian Craciun and finally Adrian Florescu. The principle of real-time hybrid designed bench was taken by other French laboratories (e.g. LEEP Lille, CEA INES, ESTIA Biarritz).

The existing platform is «Energy» oriented: Electronic Power Systems for the network, Photovoltaic Generation, Wind Generation, Hydraulic and Hydroelectric Generation, Protection Systems, Special Networks (Electric Vehicle, Smart Home Networking, Datacenter).

This platform has achieved the following results : The first HIL test with an emulated wind generator connected to a simulated network with ARENE URT and the first HIL test of protection relays at real powers with RT Lab.

Realtime simulation

PV generation systems and intelligent-house energy management

The test bench structure is composed of test bench hardware (power interface) and of software (control system, mathematical PV model) implementation aspects. The hardware part is composed of a DC source or power amplifier in order to emulating the grid, PV generation system, a Boost converter and an inverter which makes it possible the connection between the emulation PV generation system and the electrical network. The test bench software contains the EMS (Energy Management System), the building model including the thermal model of the room, the control strategies for the real power electronics (Boost converter, inverter) and the model for the electrical network. The above-presented models of the software part are implemented in RT-Lab HILBox 4U digital system or are implemented using dSpace hardware (DS1005). It provides tools for running simulations of highly complex models on a multi-processor architecture communicating via ultra low-latency technologies, in order to achieve high speed computations. RT-Lab and dSpace handles synchronization and real-world interfacing using fast I/O boards and data exchanges for HIL/PHIL applications. The generation chain mathematical model is implemented in Matlab/Simulink, then compiled and loaded into the above-described hardware. The variables computed according to the mathematical PV model or intelligent-house are filtered, mapped into -10 and 10V interval and then outputted to the RT-Lab and dSpace analog outputs.

Why using Realtime simulation and PHIL simulation ?

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FURTHER READING

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