DERri
Distributed Energy Resources
Research Infrastructures

TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	EnergyMAD
User-Project Title	Energy Transfer Models for Active Distribution Grids
Main-scientific field	Electrical engineering
Specific-Discipline	Power engineering

Lead User of the Proposing Team:

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Position in Organization	Professor / team leader

* 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)

Additional Users in the Proposing Team:

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Organization name, web site and address	MicroDERLab – www.microderlab.pub.ro
Activity type and legal status* of Organization	(1) research group within a Higher Education Institution: University POLITEHNICA of Bucharest
Position in Organization	PhD student / Assistant researcher

* 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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Position in Organization	PhD student / Assistant researcher

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Activity type and legal status* of Organization	(1) research group within a Higher Education Institution: University POLITEHNICA of Bucharest
Position in Organization	Lecturer / Researcher

Date of submission	31 January 2012
Re-submission	YES_____ NO___X____
Proposed Host TA Facility	EDF, France; IWES, Germany; ICCS-NTUA, Greece; RISOE, Denmark
Starting date (proposed)	1st May 2012

Summary of proposed research (about ½ page)

Smart Grids paradigm includes the future control of distribution grids which evolve as to accommodate novel components - distributed generation (DG) units, mobile storage (including e-mobility) and prosumers [1, 2]. The energy transfer will be analyzed within both DC and AC paradigma. The proposed project aims at performing an accurate network *analysis* by taking into consideration: **uncertainties associated with measurement systems**; **new quantities to be monitored** in distribution networks beyond the steady state paradigm based on data aggregation (rate of change of frequency, voltage and current phasors); **newly devised numerical models** of the elements of active distribution networks, including power electronics interfaced DG and storage. The topics above represent **the three dimensions of the project** and include advanced data processing associated to long term monitoring. When related to classical fields of study in power engineering, the project encompasses power quality studies, microgrids, and measurement techniques.

State-of-the-Art

Traditional power systems operation considers for both steady state conditions and dynamic responses adequately developed control algorithms which aim at regulating large synchronous machines with high inertia. Connecting intermittent, non controllable generation sources with the electrical networks has generated several challenging problems – for example, transfer of the stability concerns to the distribution grids. Also, because the generation layer incorporates distributed generation (DG) characteristics, the control layer has to be re-designed, as to adapt to lower time constants (in range of hundreds of milliseconds), or to conflicting settings due to non-harmonized regulations (example: voltage ride-through requirements and distance protection selectivity [3]).

Recent efforts focus on the capability of decentralized generation to provide *system services* and on control algorithms beyond satisfying electricity demand, within complex architectures like the virtual power plant concept [4]. In addition, the topic of lower inertia introduced by high share of generation interfaced by static converters [5, 6] is addressed from a wider perspective, including the storage units [7] and advanced measurement and control solutions (public results of the FP6/7 projects: EU-DEEP; GrowDERs; Fenix; ADDRESS, VSYNC, WindGrid etc.).

Active electrical distribution networks [8, 9] bring new topics to be solved and concern: steady-state and disturbances constraints; power quality; secondary control; contribution to the ancillary services; ride-fault through capability and protection settings divergent requirements; (intentional) islanded operation; system reliability. In this context, the ancillary services (voltage control; frequency control; stability control; black-start capability) are becoming critical for the reliable and secure operation of the power systems [10, 11]. Because the balancing costs depend on the power reserves type, the efficient integration of the DG sources in the power systems requires the fully use of the generation units capabilities so that an optimum situation can be reached.

Integration of DGs in the existing distribution electrical networks and the foreseeable need of providing system services to the grid require real-time estimation of their operation and therefore detailed analysis capability, on-line monitoring and reliable models [12].

In order to *appropriately coordinate* and *operate* the distribution network, the control centers need information regarding the DGs operation and the network state in the point of common coupling. Information exchange is vital so the development of the communication links between the DGs and the distribution operator are expected in the near future to allow *real time information exchange*. Control algorithms have to rely on accurate information but presently measurements, models and estimators fail to process uncertainties associated with the limited knowledge on the functionality of the emerging intelligent network. One important line of research is the progressive use of synchronized measurements [10,14], mostly in form of Phasor Measurement Units (PMUs).

Deployment of PMUs in distribution networks will take full advantage of their additional functionalities (power quality monitoring, remote access, high accuracy) and new application areas are shaped [15]. Also, novel data aggregation and processing methodologies and algorithms are investigated.

The project proposal is also a consequence of the new approach dedicated to innovative technologies for integrating distributed and intermittent sources (DG) into distribution networks [11]. As several renewable sources and the presently available storage systems deliver electricity in DC form [13], it appears that the logical solution is to link them all in a DC grid and to distribute the power in DC form. Therefore, both solutions have to be studied and compared. Under study are stability issues, control, protection, commutation technologies, power quality (PQ), and quality of service. As the core of such networks are the power converters, with dramatic impact on the power quality parameters, *this project will provide a comprehensive analysis of the available and emerging solutions for DER integration into active distribution networks, able to function in either connected or island mode*. Topics like power quality (PQ) aspects in DC grids, together with e-mobility and communication in Smart Grid [20-21] define a resourcefull research area.

References

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

The aims at developing qualitative and quantitative assessments of the power quality problems occuring in active distribution grids. These assessments will enable stakeholders to compare the proposed solutions to present technologies (which make almost exclusive use of AC passive distribution networks). The future power system will comprise multiple generation and storage nodes, DC/DC and AC/DC converters, and a multitude of loads. These loads will have a front end AC/DC converter and a transformer link to the main AC distribution grid, allowing bi-directional energy transfer, with or without high-frequency intermediate transformers. The main scientific purpose of our project is to focus on power quality issues, including quality of service definitions with quantitative descriptors.

The main objectives of this project can be summarized as follows:

- To take advantage of world-class laboratories by performing sets of experiments in a high quality research environment;
- To gain knowledge on hot-topics in electrical engineering targeting the distribution network evolvement towards smart grid.
- To improve team-working skills and pursue interdisciplinary research with high-potential of being disseminated in recognized publications.
- To initiate and foster collaborations in view of pursuing future research projects enabling a European-wide impact.

The PQ analysis dimension will comprises of experimental work regarding the harmonic distortion levels produced by the grid connected sources and / without filtering solutions. Envisaged experimental work consists in the evaluation of current harmonics injected into the grid by three DG units: a PV power plant, a wind turbine and a battery charging system. An eficiency evaluation of the existing filtering solutions together with the analysis and identification of best

power quality improvement solution in each case will be pursued.

Integration of DGs in the existing distribution electrical networks and the foreseeable need of providing system services to the grid require real-time estimation of their operation as well as supervising algorithms for network reconfiguration, both for technical and economic reasons. This is leading to need of systems capable of controlling the electrical network. One of the subjects studied by MicroDERlab research group is the development of a Virtual Synchronous Machines (VSG's) for grid parameters stabilization. The subject was studied from the point of view of frequency stabilization in an FP6 European project VSYNC. Part of the project follow-up, a PhD thesis is being developed by eng. Mihai CALIN that uses the VSG to control the grid voltage. In order to test the control algorithm that is under development, an infrastructure capable of emulating the behavior of the grid with several controllable loads, uncontrollable generation units is needed. Mainly the system should be capable of emulate a grid with a significant share of decentralized generation and to have attached a power electronics programmable converter that could act on the grids parameters. The expected outcome should be the testing of the control algorithm on a network as close as possible to the scenario of future grids. This should provide the necessary data for the PhD thesis and also should be the subject of a paper to be presented in an ISI publication.

The activities which are envisaged to be carried out at IWES premises regards power quality and distributed generation. For this matter, eng. PhD Radu Porumb intends to test the influence of various DG generators on interruption times (both short and long duration) of MV and LV networks. The test setup will allow the assessment of both power quality and reliability of distribution systems. An alternative solution, that would improve the power quality would be the development of DC microgrids.

First promising applications are built around low & medium power industrial loads and on concepts related to dispersed generation and their efficient integration into intelligent networks. One of the research groups past projects became a starting point for the technology dedicated to applications that are using electrical energy in DC form, avoiding unnecessary double transformation. The key elements are stability issues, including protection and control and the power quality corresponding to DC solution. The project will focus on elaborating the control model of a grid with multiple generation nodes, comprising various types of converters, a multitude of loads with different characteristics and power profile (specific to high the buildings: IT equipment, communication, lighting, air conditioning etc.), of storage units (batteries and super-capacitors), and the link to the main AC distribution grid allowing bi-directional energy transfer.

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

The increasing interest in the concept of Distributed Generation (DG) is due especially to the unprecedented development of grid connected Renewable Energies (RE) harnessing technologies. The conversion of the RE into electricity and the injection of the electric power into the grid is of great importance for the global economy since the non-conventional sources increase the energy supply security, reduce the dependence on the classical fossil fuels and contribute to the environment protection by reducing the greenhouse gases emissions.

Harmonic propagation in a Smart grid structure is a key aspect that needs to be studied in order to coordinate installation of different equipment for voltage control, active harmonic filtering, etc. It is envisaged to undertake power quality measurement campaigns in various points of the network, in order to analyze power quality impact and disturbance propagation in the considered grid.

Regarding microgrids subject, the project proposes a more efficient power distribution for loads which are able to operate directly at DC (as for example the fluorescent compact lamps) and both solutions (AC and DC supply) have to be studied and compared from the user point of view. Under study are stability issues, control, protection, commutation technologies, power quality (PQ), and quality of service. As the core of such networks are the power converters, with dramatic impact on the power quality parameters, this project will provide a comprehensive analysis of the available and emerging solutions for DER integration into active distribution networks, able to function in either connected or island mode. The MicroDERLab team had undergo three research projects (DCiDER: Emerging DC Distribution Grids for Optimal Use of Dispersed Generation), DCnet (DC Distribution Networks for Industrial Applications) and ENHIT (Emerging technologies for power supply of high-tech buildings) targeting activities in research areas related to that of the proposed project.

Some of the issues in the work plan require intensive scientific research (theoretical, modeling, simulation, and laboratory testing) as there is little work done and reported within the international community, especially on DC alternative of the active networks. Our research will focus on voltage sags, over-voltages, unbalance, harmonics and high frequency distortions.

Proposed Host TA Infrastructure/Installation – Justification (about one page)

The location chosen to do the experimental research of **Tiberiu Tudorache** is the MIRE (Measurements and Information System of Electrical Networks) Laboratory of Electricité de France (EDF), Site des Renardières, France. The host laboratory is involved in the research in the domain of grid connected RE systems, power quality and monitoring systems and has a rich experience in this specific area. The tests will be carried on by Associated Professor Tiberiu TUDORACHE.

The experimental infrastructure of the MIRE Laboratory is suitable for the envisaged research study since it includes a Concept Grid, fed by the French distribution grid through a 63/20 kV transformer and by various DGS such as PV, wind power, generators, batteries etc. The existing electric loads are both physical and simulated and they consists in office buildings (including electrical heating), small houses equipped with domestic appliances, heat pumps, electrical vehicle supply equipment, motors, lump impedances etc.

The experiments will be carried out using the measurement and monitoring resources available in the MIRE Laboratory.

Possible risks in the experimental study may come from the lack of sufficient wind resource for carrying out the measurements. A solution to overcome this inconvenience consists in the use of previously registered data accessible in the database of the MIRE Laboratory recorded in periods with higher wind resources.

The experimental investigation results and the practical experience gained by the visiting researcher during his activity in MIRE Laboratory are valuable since they may enrich his expertise in the domain of RE systems, DG and power quality, representing a useful knowledge for his future didactical and academic research endeavors.

The TA infrastructure that best serves the scope of the research for the third objective is the RTDS and Triphase Power Electronic converter in Institute of Communication and Computer Systems - National Technical University of Athens because the control algorithm was developed on a similar Triphase Electronic converter. The system also has the capability of Hardware-in-Loop simulation of power networks in real-time. Research on voltage control will be pursued mainly by eng. **Mihai Calin** while DC microgrids topics will be studied by dr. **Mihaela Albu**.

The activities which are envisaged to be carried out at IWES premises regards power quality and distributed generation. For this matter, dr. **Radu Porumb** intends to test the influence of various DG generators on interruption times (both short and long duration) of MV and LV networks. The test setup will allow the assessment of both power quality and reliability of distribution systems.

The experiment that should be carried out by Radu PORUMB is the simulation of a simple MV

and LV distribution system behavior. This activity will require the creation of an electric network which will contain the main generation-type units, AD and/and DC distribution, both AC and DC loads as well as DC-based distributed generators. The above mentioned test setup will enable the assessment of the ride-through-fault of the network, as long with its fault resilience.

The TA infrastructure from DERri which suits bests the testing requirements is IWES – SYSTEC, due to the fact that it holds a configurable distribution grid sectors (low and medium voltage), as well as a route offering the possibility to test inductive charging systems

The most suited test site for the research envisaged by PhD student **Marius-Andrei Roncea** would be the RISOE, Denmark, National Laboratory for Sustainable Energy within the Technical University of Denmark (DTU) given the fact it has most of the types of distributed generation and controllable loads. Also, the data storage, measurement and I/O interfaces provide access to all the data regarding generation and loads.

Synergy with ongoing research (about ½ page)

The MicroDERLab is actively involved in European and national projects like: **COST Action IC0806**: *Intelligent Monitoring, Control and Security of Critical Infrastructure Systems* and the national funded IDEI-type project: *Active Distribution Grids. Model Identification and Analysis Using Synchronized Measurements* – **ActiveDGModel**. The project aims at performing accurate network analysis by taking into consideration: uncertainties associated with measurement systems; new quantities to be monitored in distribution networks beyond the steady state paradigm based on data aggregation (rate of change of frequency, voltage and current phasors); numerical models derived for all elements of active distribution networks, including power electronics interfaced DG and storage.

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 integration and dissemination of the results will be achieved through presentations at international conferences and electric utilities, technical papers in international journals, and a project webpage under www.microderlab.pub.ro. The PhD students (Mihai Calin and Marius Andrei Roncea) and post-doctoral associates (Tiberiu Tudorache and Radu Porumb) will be strongly encouraged to play an active role in the publication and presentation of the research findings. The financial support of DERri will be highlighted in all publications, lectures, and other forms of dissemination of results. The acquired knowledge will enable our team to qualify for partnership in future consortia applying for projects under FP7 and FP8 and an

increased competitiveness in research proposals targeting national funding.

MicroDERLab has strong partnership with Romanian utilities and it is expected a high interest for the EnergyMAD results, which will be presented to DSOs and also to the regulatory energy authority. Finally, it is expected that the results of these projects and the experience gained, will contribute to revise IEC standards or promote new standards on this issue. Dr. Albu is involved in several relevant standardization committees in Romania (ASRO) and their liaisons to the IEC. Also, it is expected that power quality studies will provide a valuable input for fostering the energy efficiency actions in Romania. The dissemination of the results is further achieved through publications in international scientific journals and presentation of the results in local and international scientific meetings. The active presence of MicroDERLab in the Romanian professional environment will ensure the best channels for dissemination of both EnergyMAD and DERri results and achievements.

Time schedule (about ½ page)

NAME	TA Infrastructure	PERIOD
Mihaela ALBU	ICCS-NTUA, Greece	1-10 June
Tiberiu TUDORACHE	EDF, France	25-30 June
Radu PORUMB	IWES, Germany	10-20 September
Mihai CALIN	ICCS-NTUA, Greece	1-30 September
Marius Andrei RONCEA	RISOE, Denmark	1-11 May or 1- 22 August

Description of the proposing team (as long as needed)

Mihaela Albu, Professor, Dept. of Electrical Engineering, Politehnica University of Bucharest,

- **Ph.D. Electrical Engineering**, Politehnica University of Bucharest, Romania, 1998, Dissertation: "*Transient Phenomena on HV aerial lines for distance protection design*".
- **Dipl. Eng. Power Engineering**, Politehnica University of Bucharest, Romania, 1987
- **Fulbright Senior Fellow** 2010 and 2002-2003 at Arizona State Univ., Tempe, AZ, USA.
- **Founder of the research group MicroDERLab** at U.P.B. (www.microderlab.pub.ro), 2007

Research areas

Wide Area Measurement systems including synchronized measurements; Smart energy grids including optimal use of renewables and real time control; smart metering technologies; DC grids; power quality and signal processing for power quality assessment, nonlinear phenomena in power systems; distributed and computer-controlled measurement systems, IEEE and IEC standards in power, power system protection, virtual and Internet-based laboratories.

Research grants (recent)

1. **ActiveDGModel**, Active Distribution Grids. Model Identification and Analysis Using Synchronised Measurements, Grant PN-II-ID-PCE-2011-3, **2012-2014**
2. **SMART REGIONS**, Promoting smart metering best practices in EU, Call CIP-IEE-2009, **2010-2013**, consortium coordinator Jyväskylä Innovation Ltd., FI; UPB Director: M. Albu.
3. **ADVANCEDGRIDS**, Enabling the integration of wide area measurement systems in the electric power grids of Cyprus and Romania, Bilateral Research Program Romania-Cyprus, Project Directors M. Albu, E.Kyriakides, **2010-2011**.
4. **VSYNC**, Virtual synchronous machines for frequency stabilization in future grids with a significant share of decentralized generation. FP6 STREP Project **2007-2010**, Project Coordinator ECN (The Netherlands); UPB Project Director M. Albu.
5. **IntelliCIS:** Intelligent Monitoring, Control and Security of Critical Infrastructure Systems, COST Action nr. IC0806 (member of the Management Committee), **2009-2013.**
6. **PQACTNET,** Power Quality Assessment in Active Distribution Networks, Project 1/nov. 2007, Bilateral Research Programme Romania-Cipru, Project Directors M. Albu, E.Kyriakides, **2007-2010**.
7. **TAMPERE,** Advanced measurement solutions and parameter estimation techniques for active distribution networks, Grant CNCSIS IDEI 1402, **2009-2011**.
8. **ENHIT**, Emerging technologies for power supply of high-tech buildings, National Research Project – PNCD II-Parteneriate nr. 21065/14.09.2007, Project co-ordinator M. Albu, **2007-2010**

Consulting experience, incl. Conference organization and chairing

- Technical Committee of IEEE Smart Measurements for Future Grids Conference, **SMFG 2011**, Bologna, 2011
- International Advisory Committee of IEEE **PowerTech 2011**, Trondheim**,** 2011
- International Advisory Committee of IEEE Applied Measurements for Power Systems Workshop, **AMPS 2011**, Aachen 2011
- Technical Program Committee of the IEEE **EEEIC 2011**, International Conference on Environment and Electrical Engineering 2011, Rome, Italy, may 2011
- Moderator, Contribution of EU technology demonstration projects (EEPR/FP7) to the development of the offshore grid, Bruxelles, 15-16 March, 2011
- CIGRE- Study Committee N **B5-41**: member WG Investigation of possibilities to improve metering systems for billing purposes in substations, 2010
- Technical Program Committee of the IEEE **EESMS 2010**, IEEE Workshop on Environmental, Energy, and Structural Monitoring Systems Taranto, Italy, 9 September 2010
- Expert the New Eurasia Foundation Moscow, Russia, on-line, 2010-2011
- Vice-Chair **Intellicis -WG 2** Reliable management and control of electric power systems**,** 2009-2014
- Technical Program Committee of the **I²MTC '09, I²MTC '08**, IEEE Instr. and Meas. Techn. Conf.
- International Advisory Committee of IEEE **PowerTech 2009**, Bucharest, June 28 2009-July 2 2009.
- Berlin, reviewer for **Euramet**, **2009-2010**, Call for Joint Researcher Project (JRP) Proposals and Researcher Excellence Grant (REG)
- 2007- 2010, Bruxelles, expert evaluator FP7 – Energy Theme, REGPOT programs
- Reviewer DESMI Program, Research Promotion Foundation, the Republic of Cyprus, 2009
- Expert NSF (Bulgaria National Science Fund), on-line, 2008-2010
- Reviewer INTAS (INTAS Council of scientists, www.intas.org), on-line, 2004-2008
- Expert GNSF (Georgia National Scientific Council), on-line, 2006- 2011

Professional Membership

- CIGRE (Conseil International des Grands Réseaux Electriques), 2009-
- VDE (Verband der Elektrotechnik, Elektronik und Informationstechnik e.V.), 2010-
- IEEE (the Institute of Electronic and Electric Engineers), senior member; (M'98, SM'08); Vice-President Technical Activities of the Instrumentation and Measurement Society, 2011-2012; Deputy President of the Romanian Power Engineering Society Chapter (RO-PES).
- IRE (Romanian Power Engineers Society - Asociatia inginerilor energeticieni din România), 2005-

Publications (ResearcherID.com: A-5538-2010)

- Books and book chapters 7; Journal articles 21; Refereed conference proceedings 60; Other publications 32; various invited presentations 50, teaching material (printed) 13; Techn. reports: 50

Tiberiu Tudorache was born in 1971, in Ploiesti, Romania. He received the B.S., M.S. and Ph.D. degrees in Electrical Engineering from University POLITEHNICA of Bucharest, Romania in 1995, 1996 and 2001 respectively.

He joined the Electrical Engineering Faculty of University Politehnica of Bucharest in 2000, where he worked first as an assistant professor, then from 2002 as a lecturer and from 2008 as an associate professor.

His current research preoccupations include renewable energy systems, numerical modeling and optimization of electrical machines and electro-technologies. He developed and taught 8 academic courses in electrical engineering domain. He is author or coauthor of about 100 papers published in national and international journals or conference proceedings. He is author or coauthor of 5 books and 2 Romanian patents.

He was director of 3 national research grants and participant at 5 national research grants and 6 international research projects with industrial beneficiaries: Electricite de France, Danieli CRD Italy, CELES France and EFD Norway.

He was scientific reviewer at more than 10 international symposiums and conferences and he is currently reviewer at 4 international journals: IEEE Transactions on Power Delivery, IEEE Transactions on Vehicular Technology, Advances in Electrical and Computer Engineering (AECE) and International Journal for Computation and Mathematics in Electrical and Electronic Engineering (COMPEL).

He is senior member of IEEE and member of several IEEE Societies: Industry Applications, Magnetics and Power & Energy.

He participated two times as invited professor at Ecole Centrale de Lille, France in 2007 and 2008.

Radu Porumb (StM'03, M'05) was born in 1977, in Romania. He has received the engineer degree in electrical power systems from the University Politehnica of Bucharest in 2001 and Ph.D. degree in electrical engineering from Politecnico di Torino, Italy, in 2005. In 2010 he was awarded a European founded postdoctoral fellowship with the research topic focusing on power quality issues of smart grids. He is also lecturer at University Politehnica of Bucharest, Department of Electrical Power Systems. His fields of interest include electric distribution systems, power quality, distributed generation, energy efficiency, computer modeling of power system reliability and smart grid topics.

Mihai Calin was born in 1986, in Romania. He received his engineering degree and MSc degree in electrical engineering from the University Politehnica of Bucharest in 2009 and 2011. As of September 2009 he was an active part of the research team for one FP6 project, one bilateral program and one national grant. Working for these contracts he participated in the development of an Matlab based algorithm for controlling a smart inverter system in order to emulate a Synchronous Generator and did a lot of experimental work (especially in the 20/0.4 kV Cheia substation) and co-authored a number of international articles. Since march 2011, he is a PhD student and benefits a European founded scholarship.

Marius-Andrei Roncea was born in 1986, in Romania. He has received the engineer degree in electrical power systems from the University Politehnica of Bucharest in 2009 and the master degree in electrical power systems in 2011. In 2011 he began his doctoral studies under the guidance of professor Nicolae Golovanov and the subject of his PhD thesis is Power quality in distribution systems with Smart Grid structure.
During his bachelor studies he worked as a technician in power systems for the designer of the Bucharest subway system, and after receiving his engineer degree he worked as an engineer. Currently he is working for TELETRANS, the EMS-SCADA administrator of TRANSELECTRICA, Romania's transport system operator.
His fields of interest include EMS-SCADA systems, power systems, power quality, distributed generation, energy efficiency, smart grid topics.