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TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

User-Project Acronym	ActiveGrid
User-Project Title	Active Distribution Grids Imbalance
Main-scientific field	Electrical engineering
Specific-Discipline	Power engineering

Lead User of the Proposing Team:

Name	Mihaela ALBU
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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	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)

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Position in Organization	Lecturer / 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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status* of Organization	POLITEHNICA of Bucharest
Position in Organization	PhD student / Assistant researcher

Date of submission	31 March 2013
Re-submission	YES_____ NO___X____
Proposed Host TA Facility	USTRAT, United Kingdom
Starting date (proposed)	24 June 2012

Summary of proposed research (about ½ page)

Power systems evolve by including new types of generation units (some of them using renewable sources of primary energy), storage, power electronics based energy transfer units and loads with flexible demand. In this context, distribution networks change dramatically in order to accommodate local generation, opening in this way the concept of active distribution grids. Technologies deployed by the power systems today make extensive use of power electronics equipment. Moreover, distribution networks design changed dramatically as accommodating generation units, opening in this way the concept of active distribution grids [R1]

The proposed project aims at performing accurate network analysis by performing Power Hardware in the Loop (PHIL) experiments designed for the purpose of studying a large number of cases related to distributed generation and active distribution grids.

Nowadays, more and more distributed generators are connected to the distribution level by the home users of the electric grid. In some of these cases, the users are connected in a single phase mode to a three phase distribution grid. These are the cases considered in our studies. Load variation on one single phase together with power injection from PV on another phase determines a non-symmetrical physical system resulting in voltage and currents imbalance.The negative and zero sequence of the voltages should be monitored. By examining the results of previous simulations was found that the voltage imbalance in the variable load connection node appears to be lower when the DG is generating power in another node of the radial network. These are the cases considered in our studies.

Also another dimension of the project will be to monitor the power quality in this new paradigm in order to find solutions to improve it.

State-of-the-Art (about 1 ½ page)

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, the generation layer changes and incorporates distributed generation (DG) characteristics - especially in distribution networks, which have been initially not designed to integrate “dispersed” generation.

The decentralized generation is now used also for providing *system services* and is controlled in some cases by factors others then the electricity demand, mostly using complex architecture like virtual power plant concept. 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 and advanced measurement and control solutions.

Active electrical distribution networks 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 [19, 10, 14, 15]. 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 to reach an optimum situation.

In conclusion, *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*.

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 [1]. 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*.

In order to perform an optimal control of [future] distribution grids, *the state estimation* has to be broadly used, similar to the classical application performed by transmission operators (TSOs); it allows predictions of the most probable state of the grid, based on the measured quantities. To estimate the state of a distribution grid, the active and reactive powers, some of the current and voltage measurements (rms values), along with their associated uncertainties can be considered.

Classical information chain processes data from a few measurement points, usually in the form of rms values of voltages and currents. The rest of the unknown quantities are computed based in this set of measurement data and using network models. Both measurements and model parameters are biased by significant values of uncertainty.

References [3, 4, 7, 8, 11-13, 16-19, 21-22] document the progress of synchronized measurements, mostly in form of Phasor Measurement Units (PMUs or synchrophasors). Deployment of several units (due to their low cost and availability) will make the acquired information useful for purposes beyond the initial task – that of an improved wide area state estimation. Moreover, the need of identifying events and their relation to observable electrical quantities in various nodes of the grid made us introducing in the associated database of several variables (i.e. the rate of change of frequency) meant to ease the identification of an event time-occurrence. In this case, we propose an evolving to a generalized instrument termed a Synchronous Measurement Unit (SMU) [2]. The main feature would be to characterize the energy transfer between various parts of the system, in the time domain, with resolution set accordingly to dominant phenomena. Additionally, in operational real time, distribution dispatchers would have awareness of the status of the system, and the measurements may be used for controls in the distribution system. The increased allowed interaction of various elements of the network (controllable loads, uncontrollable generation, market –driven network configuration, smart metering bi-directional information exchange [20], increased share of mobile electrical energy hubs – for example charging/discharging unpredictability of the electric cars), makes necessary a statistical approach of the power system functionality. Such an approach is less suitable to the in use network models based on linear, fully controllable energy transfer in a-priori completely described physical network.

References

[1] FP6 ADINE project www.hermia.fi/in_english/services/coordination-of-programmes-and-p/adine/, last accessed on April 29th, 2011

[2] M. Albu, Gerald T. Heydt, S. Cosmescu, Versatile Platforms for Wide Area Synchronous Measurements in Power Distribution Systems, *Proc. of North American Power Symposium NAPS 2010*, Arlington, TX, 26-28 Sept. 2010,.

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A. G. Phadke et al., "Synchronized sampling and phasor measurements for relaying and control," *IEEE Trans. Power Delivery,* vol. 9*,* pp. 442-452, Jan. 1994.
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[17] G. Phadke et al., "Synchronized sampling and phasor measurements for relaying and control," *IEEE Trans. on Power Delivery*, vol. 9, pp. 442-452, Jan. 1994.
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[21] V.Terzija, M.Kezunovic, "Synchronised measurement technology for analysis of transmission lines faults", *Proceedings of the 44th Hawaii International Conference on system sciences*, 2011, ISBN: 978-1-4244-9618-1
[22] J. Zhang, G. Welch, "Observability and estimation uncertainty analysis for PMU placement alternatives", *Proceedings of the 2010 North American Power Symposium (NAPS 2010*), Arlington, TX, U.S.A., September 26–28, 2010.

List relevant References

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

Integration of distributed generators (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. 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. [1]. The decentralized generation is now used also for providing system services and is driven by other means then the electricity demand, mostly using complex architecture like virtual power plant concept. However, there is presently a gap between the traditional planning approaches (and underlining assumptions like symmetry, limited waveform distortion, simplistic load modeling etc.) and the operation of the existing distribution grid as a wide interconnection of active finite power systems.

Nowadays, more and more distributed generators are connected to the distribution level by the home users of the electric grid. In some of these cases, the users are connected in a single phase mode to a three phase distribution grid. These are the cases considered in our studies.

The Power Hardware in the Loop (PHIL) experiments will be designed for the purpose of studying a large number of cases related to distributed generation [2]. The laboratory setup needed should be composed of an RTDS (real time digital simulator) that can be connected to different hardware through a power amplifier . Topology and data from a real distribution network that exists in Cheia in Romania will be used as a testing framework. This network is fed by a 20/0.4kV transformer rated at 100kW. 3 main lines are connected to the 0.4kV bus. Each of the 3 lines feed single phase and 3 phase loads. For the intended case, in the simulation, DGs will be added in the form of PV panels in the connection points of different single phase loads. In order to have a better accuracy, data for the solar radiation could be added from past monitoring. A single phase variable load should be emulated using a hardware variable resistor connected to the real time simulation using the power amplifier.

Load variation on one single phase together with power injection from PV on another phase should determine a non-symmetrical physical system resulting in voltage and currents imbalance.

The negative and zero sequence of the voltages on the LV side of the transformer and at the connection point of the variable load in case of PV power injection and without PV injection will be monitored. By examining the results from previous simulations it was found that the voltage imbalance in the variable load connection node appears to be lower when the PV is generating power in another node of the radial network.

Some of the issues that appear in the described network can be solved by the deployment of a STATCOM device in the network. A rapid prototyping platform rated at 90kVA exists physically in the network used as a model. The platform can be programmed to work as a STATCOM. Another aspect that the project proposes for study will be to study the optimal placement of the STATCOM device in order to have the highest efficiency.

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

The increasing interest in the concept of Distributed Generation System (DGS) 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 from different sources is a key aspect that needs to be studied in order to coordinate installation of different equipment for voltage control, active harmonic filtering, etc. We would like to make power quality measurements in some points of the network, especially near the generation, in order to analyze power quality impact and disturbance propagation in the active grid.

Data collected from the distribution grid are used in customer services, in network designing and operation and for outage statistics. In order to control the distribution grids, the state estimation needs to be broadly used, similar to the classical application performed by transmission operators (TSOs), so it can predict the most probable state of the grid, based on the measured quantities. In order to be able to do this it is very important to have an understanding of the grid model and its behavior.

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

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The location chosen to do the experimental research is the Distribution Network – Automation and Protection Laboratory at the Institute for Energy and Environment at the University of Strathclyde. The D-NAP facility best fits our project due to the fact it can be used for hardware in the loop (HIL) simulation. Using HIL it is possible to demonstrate a small network and distributed resources attached to a much larger electrical network, for instance the utility grid. This is the exact case of the test framework network in Cheia. Field test for Voltage control of this distribution network are programmed for August so accurate simulations before that date are highly considered.

Synergy with ongoing research (about ½ page)

The MicroDERLab is actively involved in european and national projectslike: COST Action IC0806: Intelligent Monitoring, Control and Security of Critical Infrastructure Systems, 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)

The integration and dissemination of the results will be achieved through presentations at international conferences and to the electric utilities, technical papers in international journals, and a project webpage developed and maintained under www.microderlab.pub.ro
Also most of the test and test results will be presented in the PhD. thesis of Mihai CALIN.

Time schedule (about ½ page)

NAME	TA Infrastructure	PERIOD
Mihaela ALBU	USTRAT, United Kingdom	27 June – 04 July
Ana-Maria DUMITRESCU	USTRAT, United Kingdom	24 June - 29 June
Mihai CALIN	USTRAT, United Kingdom	24 June - 24 July

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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

Ana-Maria Dumitrescu was born in Bucharest, Romania in Aurgust 1079. She graduated as an engineer in Electrical Engineering in 2003 and received the Ph.D. title from the Politehnica University of Bucharest in 2012. She started as Assistant Professor at the Electrical Machines, Materials and Drives Department in same University in 2005 becoming lecturer in 2013. She worked on a number of 8 national and 6 international projects and co-authored a number of 30 papers in the electrical engineering field. Her area of interest includes: Control strategies, power quality, electrical measurements.

Mihai Calin was born in 1986, in Romania. He has recived 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 an European founded scholarship.

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