DERri
Distributed Energy Resources
Research Infrastructures

# TEMPLATE FOR PROPOSAL UNDER DERRI

**User-Project Proposal:**

| | |
|---|---|
| User-Project Acronym | More MoDERN |
| User-Project Title | More Modelling of Distributed Energy Resources Networks |
| Main-scientific field | Smart Grids |
| Specific-Discipline | Analysis of the Dynamic Performance of Microgrids |

**Lead User of the Proposing Team:**

| | |
|---|---|
| Name | Grigoris Papagiannis |
| Phone | +302310996388 |
| E-mail | grigoris@eng.auth.gr |
| Nationality | Greek |
| Organization name, web site and address | Aristotle University of Thessaloniki, Department of Electrical and Computer Engineering, Power Systems Laboratory, http://power.ee.auth.gr, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece |
| Activity type and legal status* of Organization | Higher Education Institute |
| Position in Organization | Associate 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)

**Additional Users in the Proposing Team:**

| | |
|---|---|
| Name | Panagiotis Papadopoulos |
| Phone | +302310996379 |
| E-mail | panpapad@auth.gr |
| Nationality | Greek |
| Organization name, web site and address | Aristotle University of Thessaloniki, Department of Electrical and Computer Engineering, Power Systems Laboratory, http://power.ee.auth.gr, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece |
| Activity type and legal status* of Organization | Higher Education Institute |
| Position in Organization | PhD Candidate |

- 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)

| | |
|---|---|
| Name | Theofilos Papadopoulos |
| Phone | +302310996345 |
| E-mail | thpapa@auth.gr |
| Nationality | Greek |

DERri
Distributed Energy Resources
Research Infrastructures

| | |
|---|---|
| Organization name, web site and address | Aristotle University of Thessaloniki, Department of Electrical and Computer Engineering, Power Systems Laboratory, http://power.ee.auth.gr, Aristotle University of Thessaloniki, GR-54124 Thessaloniki, Greece |
| Activity type and legal status* of Organization | Higher Education Institute |
| Position in Organization | Post doctoral researcher |

| | |
|---|---|
| Date of submission | 30/11/2012 |
| Re-submission | YES_______ NO__X_____ |
| Proposed Host TA Facility | TA13 University of Strathclyde |
| Starting date (proposed) | 10th February |

**Summary of proposed research (about ½ page)**

Scope of this proposal is to investigate the influence of the different inverter-interfaced and directly AC connected DG units on the dynamic performance of microgrids. Special emphasis is given on the different control strategies used by the DG units as well as on the second-level operation strategy adopted in the microgrid, in order to analyze their impact on transients and on the stability of the microgrid.

Experimental measurements from the test facility will help in the implementation of a systematic methodology and guidelines to investigate the influence of the control strategies on the dynamic performance of the microgrid and the DG units individually. For this purpose dynamic measurements from the test facility are necessary, in combination with proper tools, such as Prony analysis and System Identification functions. The obtained measurements will be the first step to further implement an optimization algorithm, considering the optimum control strategy applied to a microgrid, according to different criteria, such as stability, losses reduction, maximize the distributed generation penetration.

**State-of-the-Art (about 1 ½ page)**

Driven by the global requirements for reliable, efficient and environmentally friendly electric power, the conventional power grid is gradually transformed to a modern one with enhanced functions, commonly described by the term "Smart Grids". Smart Grids are intelligently, controlled active networks, that facilitate the integration of distributed generation (DG) into the power system [1].

The types of DG units used depend on their application and energy source, presenting significant differences in performance, power capacities and generation characteristics. Diesel and asynchronous generators are directly ac coupled to the grid, while other, either static or rotating are connected through power electronic converters, allowing great flexibility and controllability [1], [2].

In this context, several techniques and power management strategies have been proposed, in order to maximize the DG penetration and the utilization of the power system. The most important are active management, virtual power plants and microgrids [1]. Especially, the development of microgrids is a very promising technology for the electric energy industry. Microgrids are small-scale autonomous networks designed to supply electrical energy and heat. From the operational point of view, microgrids are active distribution networks, facilitating the integration of distributed generation units, offering several advantages; the most significant being the reduction of the physical and the electrical distance between the source and the loads, the improvement of power quality, the reduction of greenhouse gas emissions and the increase of the reliability of energy suppliers [2].

In microgrids two control strategies of the DG units are usually adopted, the peer-to-peer and the master-slave control [1] - [3]. In master-slave control the slave modules receive instructions from the master unit through communication channels. Two master-slave control modes have been proposed. One adopts a single DG unit as the master, while in the second a central controller is used to supervise DG units and loads [1], [3]. On the contrary in peer-to-peer control each DG unit has an equivalent status. The microgrid can operate autonomously and continuously without any communication system by using real and reactive droop-based local controllers, thus achieving plug-and-play capability [1], [3], [4]. The latter control strategy is attracting continuously the research interest in the area of microgrids.

However, high penetration of DG units in microgrids creates a number of issues, considering the stability and the protection coordination of the microgrid, when small or large disturbances occur, such as switching events and faults [5], [6]. The overall short circuit capability of the power system decreases and the trip currents of the circuit breakers need to be reconsidered or even updated in real time, depending on the type and number of DG units connected [7]. Moreover, storage devices, which can also act as controllable loads, need to be integrated in order to provide power during faults, balance the intermittency of renewable energy sources and thus enhance the dynamic stability of the system [8]. New control and power management strategies for both DG units and storage devices need to be implemented in order to achieve secure and reliable operation of the power system [9]. Fully controllable power sources such as Fuel Cells (FCs) and MicroTurbines (MTs) that are not intermittent can also be used to increase the stability of the system [9]. This way maximum DG unit penetration and utilization of the power system can be achieved.

Therefore, several research studies focus on the dynamic security assessment (DSA) and the evaluation of the transient performance of microgrids, in order to improve the dynamic performance and increase the stability of the system [7], [10]. These approaches use mainly proper simulation tools, such as PSCAD/EMTDC [10], [12] and Matlab/Simulink [6], [9] as well as proper computational techniques, such as eigenvalue analysis [6].

Only recently some laboratory-scale microgrid systems have been developed [13] - [16], providing a reliable verification platform and a valuable tool for experimentation, practical research and investigations including: a) studies on the operational control strategy and development of microgrids b) studies on the impacts of microgrids on power systems c) analysis of the economic efficiency and social benefits of microgrids and d) formulation of guidelines regarding microgrids and implementation of microgrid security access to the utility grid [13].

**References**

[1] N. Jenkins, J.B. Ekanayake, and G. Strbac, Distributed Generation, London: The Institute of Engineering and Technology, 2010.
[2] S. Chowdhury, S. P. Chowdhury, and P. Crossley, Microgrids and Active Distribution Networks, London: The Institute of Engineering and Technology, 2009.
[3] J.A. Pecas Lopes, C. L. Moreira, "Defining control strategies for MicroGrids islanded

operation," IEEE Trans. on Power Systems, vol. 21, no.2, pp. 916-924, 2006.
[4] S. Krishnamurthy, T.M. Jahns, R.H. Lasseter, "The operation of diesel gensets in a CERTS microgrid," in Proc. 2008 IEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, pp.1-8, 20-24 July 2008.
[5] F. Katirei, and M. R. Iravani, "Power Management Strategies for a Microgrid with Multiple Distributed Generation Units," IEEE Trans. on Power Systems, vol. 21, no.21, pp. 1821-1831, Nov. 2006.
[6] Z. Miao, A. Domijan, L. Fan, "Investigation of Microgrids with Both Inverter Interfaced and Direct AC-Connected Distributed Energy Resources," IEEE Trans. On Power Delivery, vol. 26, no. 3, July 2011.
[7] N. D. Hatziargyriou, A. P. Meliopoulos "Distributed Energy Sources: Technical Challenges," in Proc. IEEE Power Engineering Society Winter meeting 2002, vol. 2, New York, NY, Jan. 2002, pp. 1017-1022
[8] Hamsic, N., Schmelter, A., Mohd, A., Ortjohann, E., Schultze, E., Tuckey, A., Zimmermann, J., "Increasing Renewable Energy Penetration in Isolated Grids Using a Flywheel Energy Storage System," Power Engineering, Energy and Electrical Drives, 2007. POWERENG 2007. International Conference on, vol., no., pp.195-200, 12-14 April 2007
[9] Al-Hinai, A., Sedhisigarchi, K., Feliachi, A., "Stability enhancement of a distribution network comprising a fuel cell and a microturbine," Power Engineering Society General Meeting, 2004. IEEE , vol., no., pp.2156-2161 Vol.2, 10-10 June 2004
[10] A.S. Emhemed, R.M. Tumilty, N.K. Singh, G.M. Burt, and J.R. McDonald, "Analysis of Transient Stability Enhancement of LV-Connected Induction Microgenerators by Using Resistive-Type Fault Current Limiters," IEEE Transactions on Power Systems, vol.25, no.2, pp.885-893, May 2010.
[11] D.J. Lee, L. Wang, "Small-Signal Stability Analysis of an Autonomous Hybrid Renewable Energy Power Generation/Energy Storage System Part I: Time-Domain Simulations," IEEE Transactions on Energy Conversion, vol.23, no.1, pp.311-320, March 2008.
[12] F. Katiraei, M. R. Iravani, and P. W. Lehn, "Micro-Grid Autonomous Operation During and Subsequent to Islanding Process," IEEE Trans. on Power Systems, vol. 20, no. 1, pp. 248-257, Jan. 2005.
[13] B. Zhao, X. Zhang, J. Chen, "Integrated Microgrid Laboratory System," IEEE Transactions On Power Systems, vol.27, no.4, pp.2175-2185, Nov. 2012.
[14] V. Salehi, A. Mohamed, A. Mazloomzadeh, and O.A. Mohammed, "Laboratory-Based Smart Power System, Part I: Design and System Development," IEEE Transactions on Smart Grid, vol.3, no.3, pp.1394-1404, Sept. 2012.
[15] D. Stimoniaris, D. Tsiamitros, N. Poulakis, T. Kottas, V. Kikis, and E. Dialynas, "Investigation of smart grid topologies using pilot installations experimental results," in Proc. 2011 2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies (ISGT Europe), pp.1-8, 5-7 Dec. 2011.
[16] A.J. Roscoe, A. Mackay, G.M. Burt, J.R. McDonald, "Architecture of a Network-in-the-Loop Environment for Characterizing AC Power-System Behavior," IEEE Transactions Industrial Electronics, vol.57, no.4, pp.1245-1253, April 2010.
[17] O. I. Elgerd, Electric Energy Systems Theory: An Introduction, McGraw-Hill, 2nd edition, 1982.

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

Scope of this proposal is to investigate the influence of the different inverter-interfaced and directly AC connected DG units on the dynamic performance of microgrids. Special emphasis is given on the different control strategies used by the DG units, in order to analyze their impact on transients and on the stability of the microgrid. Microgrids require control to ensure system

security, optimal operation, emission reduction and seamless transfer from one operating mode to the other without violating the system constraints and regulatory requirements. This control is achieved through a master-slave or a peer-to-peer strategy. The stability of the microgrid under grid-connected and mainly under islanded operation is of considerable importance, since it the low-inertia DG unit interfaces tend to make the microgrid sensitive to disturbances. The microgrid stability is significantly affected by the parameters of the control strategy adopted in the microgrid, the dedicated DG unit and storage devices controllers. An in depth understanding of the effect of the above system properties is required, in order to allow Energy Management Systems (EMS) to apply real-time optimization through adjustment of DG outputs, to minimize costs, losses or achieve other targets.
More specifically the main features and targets of the proposed research project are:

- to conduct detailed experiments-parametric analysis, in order to investigate thoroughly the influence of the different control strategies and control parameters of each case,
- to propose a methodology-guidelines considering the analysis and the design of the power management of microgrids,
- to implement a sensitivity analysis on the measurements of the microgrid dynamic response,
- to compare systematically the different control strategies adopted in a microgrid and highlight the advantages and disadvantages of each method,
- to investigate the effect of generation type and penetration, load type and size on the stability of the microgrid,
- to investigate the dynamic performance of each DG unit individually as well as the interactions between the different microgrid devices in cases of dynamic disturbances.

The proposed methodology will include:

- measurements of the active and reactive power of the microgrid and the different DG units, bus voltages, system frequency, branch currents, recorded for different test cases,
- implement an analysis in terms of the dynamic/transient performance and the stability of the microgrid, using Prony analysis and System Identification methods,
- from the obtained results propose a methodology-guidelines for the efficient operation of the microgrid.

Most similar research works found in the literature, are based on simulation analysis and computational tools. However, the main feature of the proposed work is that it is based on measurements obtained from experimentation in a real-world microgrid, which has not yet been conducted thoroughly. Furthermore, the proposed study will provide detailed analytical results, and remarks, considering the dynamic performance of the DG units, the microgrid and the stability of the system.
The theoretical analysis of the obtained responses will be evaluated using proper tools, including Prony analysis and the System Identification Toolbox of Matlab/Simulink, in order to investigate the nature of the microgrid dynamics as well as to perform a sensitivity analysis on the dynamic performance of the system. The analysis of the microgrid system oscillatory damped dynamic responses will reveal the frequencies involved and thus the modes of operation of the system, which are directly related to the corresponding DG units electromechanical and control characteristics. Furthermore, using Prony analysis the influence of each examined parameter will be evaluated. For example, the effect of the frequency-active ($f$ - $P$) power droop characteristics of the inverter interfaced units on the microgrid dynamic response under grid-connected and islanded mode of operation.
The proposed project is based and motivated by the results and the cooperation of the research groups of the Power Systems Laboratory of the Aristotle University of Thessaloniki and of the University of Strathclyde under the MoDERN project, implemented in the frame of the DERri program. Scope of the first edition of the MoDERN project was to implement a dynamic equivalent model of microgrids based on Prony analysis and measurements taken from Phasor Measurement Units (PMUs) following a black box approach. The model can be used for

transient, small signal, voltage and frequency stability analysis and it can represent the microgrid active and reactive power flow at the Point of Common Coupling (PCC), when different types of disturbances occur. Results from the MoDERN project highlighted the necessity to investigate thoroughly the influence of the control strategies adopted for the microgrid operation and the DG units individually.

This work is also a sequel and a step further to implement a more detailed and analytic model in the concept of Dynamic Network Cell (DNC), based on the grey-box approach. In the black-box modelling, the topology of the model is known a priori. The only concern there is to map the input data set to the output data set in such a way that the output of the model and the output of the modelled system are the same. The grey-box model is typically developed using a known structure of the system (but not exact composition of physical components) with unknown parameters. The parameters are then estimated in a similar way as those in case of the black-box model. In the grey-box approach the development of the equivalent model assumes a known topology of the microgrid and estimates the parameters of the model from online or offline measurements. The adopted model structure represents the dominant behavior of the DNC system and leaves the mismatch part of the system to be approximated by an optimization method. Thus, it is important to carefully select and use the right model structure which will allow a better estimation of the model of DNC. This idea stems from the fact that grey-box approach has the potential to significantly improve the accuracy of DNC model than a black-box approach as the structure of the system is known.

The expected outcome of the project and the fundamental scientific and technical value will be:

- A methodology to systematically investigate the influence of the control strategies on the dynamic performance of the microgrid and the DG units individually.
- A first step to investigate experimentally the capabilities of secondary control strategies of DG units in microgrids to provide some basic ancillary services to the grid particularly during system stress (e.g. *f* - *P*, *V* - *Q* control)
- Provide deeper understanding of the microgrid stability, making feasible to implement more sophisticated DG droop settings in islanded microgrids and further improve their performance
- Improve the black-box model proposed by the research groups of the PSL and Strathclyde University and enhance it to a grey-box more detailed model
- Highlight further areas for investigation.

For the purpose of the analysis an extensive set of measurements from a microgrid test set up is needed. The Various operating conditions will be examined for different mix of power sources, storage devices and loads. Available measurements at each DG unit node will be used in order to determine the degree of the influence of each sinlge unit on the proposed model.

The test set-up should comprise of a fully controllable microgrid. The examined microgrid topology should contain different types of distributed generation (DG) sources, either conventionally directly connected to the ac part of the microgrid or inverter-interfaced and loads. It is of significant importance that the microgrid DG units adopt different inverter-based DG control strategies, since these units are the major power sources in the microgrid, determining decisively the stability of the system. At present there are three inverter-based DG control strategies:

- PQ control: enabling the output power of the DGs to equal the corresponding reference values. PQ control generally adjusts the decoupled active power and reactive power, respectively.
- V/f control: Regardless of the power changes of DG, the purpose of V/f control is to keep the voltage and frequency of the inverter connected bus system unchanged.
- Droop control: Droop control simulates the power-frequency static characteristics of the generator, which can provide voltage and frequency support. The units adopting droop control can provide voltage and frequency support separately or combined with other

units.

Furthermore, the following two system/secondary-level control modes of the microgrid operation should be investigated:

- Master-slave control: referring to the operation mode in which only one DG adopts V/f control to provide the reference voltage and frequency, while the other DGs adopt usually PQ control.
- Peer-to-peer control: each DG has the same status and is controlled by the local voltage and frequency, using a proper method. The method currently of interest is the droop control.

Appropriate metering devices should be installed at each network node, able to measure voltages, currents, real/reactive power output and frequency with fast sampling times in the order of a few ms at least. The metering devices must have a significant high sampling rate, in order to record with high precision the dynamic responses of the DG units, during the transient phenomena.

The proposed experimental setup will include in general the following main features, giving special emphasis in each case in the influence of the control strategies adopted by the DG units and the microgrid secondary operation.

- Grid – connected mode of operation. The microgrid is controlled using two techniques. In the first case the microgrid complies with distribution network rules without participating in the operation of the utility system. In the second case, the microgrid provides ancillary services to the utility grid and is very important to sustain the stable operation of the power system.
- Islanded mode of operation. Both the master-slave and the peer-to-peer operation strategies will be examined, considering the islanded mode of operation.
- DG units operating either in PQ and droop controlled operation
- Parametric analysis on the influence of the control properties, e.g. *f-P* and *V-Q* droop gain
- Static and dynamic load changes in the operation state (step changes in the power output)
- Frequency variations
- DG units change in the operating point (step changes in the power output)

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

The proposed work will contribute in the development of a systematic methodology, in order to investigate the influence of the control strategies on the dynamic performance of microgrids. The research work will provide a deeper understanding of the microgrid dynamic performance giving special emphasis in the stability of the system. Therefore, mores sophisticated control strategies can be proposed, which would further improve the performance of microgrids.

Additionally, the proposed methodology can be used to design control strategies that will utilize the DG sources more effectively, thus maximizing the DG unit penetration without compromising security and reliability of the power system.

Another innovative approach is that the proposed systematic methodology and the analysis conducted will be based on measurements in a real environment of a laboratory scale microgrid and not on simulation results obtained from software tools. Experimental results found in the literature are still very limited, especially in topologies of integrated microgrid systems. Therefore, this practical approach will shed light to many practical problems that may arise in the process. A first step to automate the procedure will be also made in order to identify possible restrictions from the hardware devices such as metering devices, controllers etc.

The black-box model approach developed from the analysis and the measurements of the first version of the MoDERN project as a result of the cooperation of AUTh and Strathclyde University, in the frame of the DERri program, will be further enhanced and updated to a grey-box model. In grey-box modeling there is an initial estimation of the structure of the microgrid, compared to the black-box approach where there is no knowledge or estimation of the topology and operating conditions of the system. Therefore, the improved model will be more detailed, including the control mechanisms of the various DG. The network reduction will aim at grouping similar power sources and loads and provide an interface for exchanging information between these entities in order to develop the overall microgrid model. Moreover the available DNCs in the literature are not targeted towards representing microgrids with high penetration of inverter interfaced units something that will be addressed in this proposal.

The proposed research is a first step to implement an algorithm, suitable for the optimum operation of a microgrid, according to different criteria, such a stability, minimization of losses, increase DG penetration or apply different types of ancillary services. This can be achieved by choosing properly the second level control strategy of the microgrid as well as by tuning properly the control properties of the different DG units and especially those that are inverter-interfaced. The systematic comparison of the different control strategies will reveal also the advantages and disadvantages of each method.

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

A complete microgrid facility should be available in the proposed host TA infrastructure. The microgrid should be able to operate in both grid – connected and islanded mode. The microgrid should be fully controllable and operate both in master/slave and peer-to-peer control strategies, while it should contain several different power sources, both renewable such as wind generators or photovoltaic, and conventional (steam/gas turbines, diesel engines). Modern storage devices such as fuel cells and batteries and static and dynamic loads are also desirable.

It is of significant importance the microgrid to include both inverter-interfaced distributed generation units as well as units directly connected to the ac part of the microgrid. Furthermore, it is necessary the inverter-interfaced units to adopt and operate with different control strategies, such as active - reactive power control (*PQ*), voltage-frequency (*f*-*V*) , frequency-active power (*f*-*P*) and voltage-reactive (*V*-*Q*) power droop control, in order to investigate the influence of the different control strategies on the dynamic performance of the microgrid as described in detail above. The parameters also of each control strategy should be adjustable, in order to implement a detailed parametric analysis. Finally suitable protection devices should be available for each unit in order to ensure that no operational limit is surpassed.

The test facility must be also equipped with a high speed data acquisition system with a time step of at least a few milliseconds (ms), in order to record with high accuracy the dynamic performance of the microgrid and the distributed generation units. Recording devices should be available at each network bus providing the ability to monitor and record the power system operational status and record dynamic phenomena such as load connections/disconnections, change in the power output of the generator units, etc. Moreover, a control room is necessary, in order to operate the different DG units simultaneously and apply the different second level control strategies in the microgrid. The controlled devices should be able to communicate with the central control computer that will generate reference signals for each DG unit and determine the appropriate control strategy.

The University of Strathclyde test facility is suitable for the proposed study. The availability of real time simulators is also of great importance due to the ability to study more complex power networks with Hardware in the Loop (HIL) simulations. Moreover, previous research work considering the improvement of the network stability using inverter interfaced units, application of control strategies for power quality issues in a microgrid supports the proposed work. The experience of the technical and research staff could be of great assistance and ensure the best possible outcome of the experiment.

According to the available information and the previous research cooperation and experience in the frame of the DERri project, the infrastructure of the Strathclyde University microgrid can cover in a high degree the requirements of the new research proposal. This is because the staff has a significant experience in implementing and applying different control strategies in microgrids. Finally, it is more important that the microgrid DG units can operate under different control strategies and operational states, which is fundamental for the success of the proposed research project.

**Synergy with ongoing research (about ½ page)**

No other similar project funded by EU or national resources is ongoing in the Power System Laboratory (PSL). This work is intended to be a sequel and a step further from a previous cooperation between the PSL of AUTH and the Strathclyde University in the frame of the DERri FP7 program.

**Dissemination – Exploitation of results (about ½ page)**

The completion of the test measurements will be accompanied by a report with the obtained data and initial experimental results. Part of the project results will be presented in an international conference in the following months after the tests are over. The complete methodology will be published in an international peer reviewed journal when the analysis will be accomplished.

Furthermore the initial results will be made public through the Power System Laboratory webpage (power.ee.auth.gr) and they will be updated with the final results of the study as well.

**Time schedule (about ½ page)**

The target starting date of the proposed study is the 15th of February or alternatively the beginning of July and the program is estimated to last about four weeks.

The first week will be devoted at organizing the test cases that are going to be conducted. The available control strategies that can be applied to the microgrid as well as the control properties of each DG unit. Preliminary tests will be also conducted, in order to check the feasibility of each test case.

During the second week systematic extensive experiments will be conducted, starting from the islanded mode of operation. The master-slave as well as the peer-to-peer control strategies are going to be examined. According to the topology of the microgrid, two possible configurations will be examined. In the first one the large generator of 80 kVA and the rest DG units will participate in the load sharing of the microgrid, while in the second configuration only the 2 kVA genset and the inverter-interfaced units will be connected. During this week results will be evaluated and analyzed, using the corresponding software tools.

In the third week similar experiments as previously will be conducted, for the grid-connected mode of operation. The same procedure considering the analysis of the results will be followed.

In the fourth week complementary experiments, according to the results of the theoretical analysis will be conducted as well as test cases with possible problems in data, measurements etc will be repeated.

The final methodology evaluation and proposal will be carried out after the completion of the experiments and the resulting journal publication and conference paper will be prepared afterwards.

**Description of the proposing team (as long as needed)**

**Grigoris K. Papagiannis** was born in Thessaloniki, Greece, on September 23, 1956. He received his Dipl. Eng. Degree and the Ph.D. degree from the Department of Electrical and Computer Engineering at the Aristotle University of Thessaloniki, in 1979 and 1998 respectively.

He is currently As. Professor at the Power Systems Laboratory of the Department of Electrical and Computer Engineering of the Aristotle University of Thessaloniki, Greece. His special interests are power systems modelling, computation of electromagnetic transients, distributed generation and powerline communications.

**Panagiotis N. Papadopoulos** was born in Komotini, Greece, on March 30, 1985. He received the Dipl. Eng. Degree from the Department of Electrical and Computer Engineering at the Aristotle University of Thessaloniki, in 2007. Since 2007 he has been postgraduate student at the same university. His research interests are in the field of power system modeling, simulation and transient analysis of distributed generation networks and smart grids.

**Theofilos A. Papadopoulos** was born in Thessaloniki, Greece, on March 10, 1980. He received his Dipl. Eng. Degree and Ph.D. from the Department of Electrical and Computer Engineering at the Aristotle University of Thessaloniki, in 2003 and 2008, respectively. He is currently a researcher at the Power Systems Laboratory of the Department of Electrical and Computer Engineering of the Aristotle University of Thessaloniki, Greece. His special interests are power systems modeling, powerline communications and computation of electromagnetic transients. Mr. Papadopoulos has received the Basil Papadias Award for the best student paper, presented at the IEEE PowerTech 07 Conference in Lausanne, Switzerland.

The Power Systems Laboratory (PSL) consists a legal entity of the Department of Electrical and Computer Engineering since 1980. It has been involved in more than 110 European, bi-lateral and national contract projects, mostly related to the research and development of power systems, renewable energy sources, electric power and consumption control, environmental impacts from power generation and applications of Information Technologies. It also cooperates closely with local energy authorities, energy market players and power producers. 16 PhD Theses have been concluded under the supervision of PSL members during the last 5 years, 4 of them on topics closely related to the field of this proposal.

The PSL laboratory equipment includes oscilloscopes, signal generators, power analyzers, electrical test instruments, data acquisition units, a complete set of LABVolt scale micromodels, including synchronous and asynchronous generators, overhead transmission lines, various transformers, power loads and DC and AC motors, capable of simulating the power system operation in steady state and transients. It also includes models of low-voltage installation protection and a full scale 20/0.4 kV substation with short overhead lines and cables for testing purposes. Two pilot installations including Medium and Low Voltage cables for PLC field test are also installed in the PSL.

Following shareware and commercial software platforms are used in the PSL for educational & research purposes ATP-EMTP, MATLAB, ANSYS, COMSOL, NEPLAN, SINCAL, EMTP-RV, GTAP, ETAP Powerstation, EUROSTAG, POWERWORLD, as well as solvers like GAMS together with software developed by members of the PSL, especially in the field of this proposal.

The staff of the PSL consists of 3 Professors, 1 As. Professor, 3 Lecturers, 3 postdoctoral researchers, 14 postgraduate students and 5 members of administrative and technical staff. The staff of the PSL has authored or co-authored in many publications in peer reviewed scientific journals and international conferences, 66 of them in topics related to distributed generation, microgrids and smart grids. More info at http://power.ee.auth.gr.

## 1.1 Research group publications

### 1.1.1 Publications in scientific journals

1. G. Papagiannis, P. Dokopoulos: '**A Simplified Frequency Independent Modal Transformation for Overhead Line Switching Transients**', *European Transactions on Electric Power Systems. (ETEP)*, Vol. 5, No. 5, Sept.-Oct. 1995, pp. 307-314.
2. D.G. Triantafyllidis, G.K. Papagiannis, D.P. Labridis: **'Calculation of Overhead Transmission Line Impedances: A Finite Element Approach',** *IEEE Transactions on Power Delivery*, Vol. PWRD-14, No. 1, Jan. 1999, pp. 287-293.
3. G.K. Papagiannis, D.G. Triantafyllidis, D.P. Labridis: '**A One-Step Finite Element Formulation For The Modeling Of Single And Double-Circuit Transmission Lines',** *IEEE Transactions on Power Systems,* Vol. PWRS-15, No. 1, Feb. 2000, pp. 33-38.
4. G. K. Papagiannis, D. A. Tsiamitros, D. P. Labridis, P. S. Dokopoulos: '**Direct Numerical Evaluation of the Earth Return Path Impedances of Underground Cables**', *IEE Proceedings on Generation, Transmission and Distribution*, vol. 152, No. 3, May 2005, pp. 321-328.
5. D.A. Tsiamitros, G.K. Papagiannis, D.P. Labridis, P.S. Dokopoulos: **'Earth Return Path Impedances Of Underground Cables For The Two-Layer Earth Case**', *IEEE Transactions on Power Delivery*, vol. PWRD-20, No. 3, July 2005, pp. 2174-2181.
6. G.K. Papagiannis, D.A. Tsiamitros, D.P. Labridis, P.S. Dokopoulos, **'A Systematic Approach To The Evaluation Of The Influence Of Multi-Layered Earth On Overhead Power Transmission Lines',** *IEEE Transactions on Power Delivery*, vol. PWRD-20, No 4, Oct. 2005, pp. 2594-2601.
7. A.S. Dagoumas, G.K. Papagiannis, P.S. Dokopoulos: '**An economic assessment of the Kyoto Protocol application',** *Energy Policy*, Volume 34, Issue 1, January 2006, pp. 26-39.
8. D.A. Tsiamitros, G.C. Christoforidis, G.K. Papagiannis, D.P. Labridis and P.S. Dokopoulos: '**Earth Conduction Effects in Systems of Overhead and Underground Conductors in Multi-Layered Soils**', *IEE Proceedings on Generation, Transmission and Distribution,* vol. 153, Nr. 3, May 2006, pp. 291 – 299.
9. A.S. Dagoumas, E. Kalaitzakis, G.K. Papagiannis, P.S. Dokopoulos: '**A post-Kyoto analysis of the Greek electric sector',** *Energy Policy*, Vol. 35, Issue 3, March 2007, pp. 1551-1563.
10. D.A. Tsiamitros, G.K. Papagiannis, P.S. Dokopoulos, **'Homogenous Earth Approximation of Two-Layer Earth Structures. An Equivalent Resistivity Approach'** , *IEEE Transactions on Power Delivery*, vol. PWRD-22, No 1, January 2007, pp. 658-666.

11. N. Protogeros, A. Economides, G.K. Papagiannis, C. Syleos, '**Developing a Near-optimal Lowest-consumption Tunnel Lighting System Using Software Agents through Power Line Communications**', *Journal of Computing and Information Technology* - CIT 15, 2007, No. 2, pp. 185–191.
12. G.K. Papagiannis, A.S. Dagoumas, N. Lettas, P.S. Dokopoulos: '**Economic and environmental impacts from the implementation of an intelligent demand side management system at the European level**', *Energy Policy,* Vol. 36, Issue 1, January 2008, pp. 163-180.
13. A.S. Dagoumas, I.P. Panapakidis, G.K. Papagiannis, P.S. Dokopoulos, '**Post-Kyoto energy consumption strategies for the Greek interconnected electric system**' *Energy Policy,* Vol. 36, Issue 6, June 2008, pp. 1980-1999.
14. T.A. Papadopoulos, G.K. Papagiannis, P.S. Dokopoulos, '**Low Voltage Distribution Line Performance Evaluation for PLC Signal Transmission**', *IEEE Trans. on Power Delivery* Vol. PWRD-23, No. 4, Oct. 2008, pp. 1903-1910.
15. D.A. Tsiamitros, G.K. Papagiannis, P.S. Dokopoulos: '**Earth Return Impedances of Conductor Arrangements in Multi-Layer Soils-Part I: Theoretical Model**', *IEEE Trans. Power Delivery.,* Vol. PWRD-23, No. 4, pp. 2392-2400, Oct. 2008.
16. D.A. Tsiamitros, G.K. Papagiannis, P.S. Dokopoulos: '**Earth Return Impedances of Conductor Arrangements in Multi-Layer Soils-Part II: Numerical Results**', *IEEE Trans. Power Delivery.*, Vol. PWRD-23, No. 4, pp. 2401-2408, Oct 2008.
17. T.A. Papadopoulos, G.K. Papagiannis, D.A. Labridis,**'Wave Propagation Characteristics of Overhead Conductors Above Imperfect Stratified Earth for a Wide Frequency Range'**, IEEE Trans. On Magnetics, Vol. 45, No. 3, March 2009 pp. 1064 – 1067, doi10.1109/TMAG.2009.2012580
18. T.A. Papadopoulos, D.A. Tsiamitros, G.K. Papagiannis, **'Impedances and Admittances of Underground Cables for the Homogeneous Earth Case'**, IEEE Trans. on Power Delivery, Vol. PWRD-25, No 2, April 2010, pp. 961 – 969.
19. T.A. Papadopoulos, G.K. Papagiannis, D.P. Labridis, "**A generalized model for the calculation of the impedances and admittances of overhead power lines above stratified earth**", *Electric Power Systems Research,* Vol. 80, Issue 9, September 2010, Pages 1160-1170 2010.
20. T.A. Papadopoulos, D.A. Tsiamitros, G.K. Papagiannis, "**Earth Return Admittances and Impedances of Underground Cables in Nonhomogeneous Earth**", *IET Proceedings on Generation, Transmission and Distribution*, vol. 5, no. 2, Feb. 2011, pp. 161 – 171.
21. T.A. Papadopoulos, A.I. Chrysochos, G.K. Papagiannis, "**An Analytical Study of the Frequency Dependent Earth Conduction Effects on Underground Power Cables**," IET Proceedings on Generation, Transmission and Distribution, to be published.
22. Ch. G. Kaloudas, T. A. Papadopoulos, K. V. Gouramanis, K. Stasinos, G. K. Papagiannis, "**Methodology for the Selection of Long Medium Voltage Power Cable Configurations**," IET Proceedings on Generation, Transmission and Distribution, to be published.
23. T. A. Papadopoulos, Ch.G. Kaloudas, A.I. Chrysochos, G. K. Papagiannis, "**Application of Narrowband Power Line Communication in Medium Voltage Smart Distribution Grids**," IEEE Trans. on Power Delivery, to be published.

### 1.1.2 Publications in conference proceedings

1. P. Dokopoulos, J. Gregoreades, D. Labridis, G. Papagiannis, A. Saramourtsis, D. Tampakis, J. Pinatsis, J. Kalogiannis, M. Pappas, P. Raftopoulos : '**Remote Control and Data Aquisition System for the Wind Energy Converters of the Greek Telecommunications Organisation**', *Proc. 3rd European Symposium "Soft Energy at the Local Level"*, Chios Island, Greece, September 1991.
2. G. Papagiannis, P. Dokopoulos: '**A simplified Real Frequency Independent Modal Transformation**', *Proceedings of the 21st E.M.T.P. European Users Group Meeting*, Crete

Greece, June 1992, Pages 6.

3. G. Papagiannis, D. Tsiamitros, D. Labridis, P. Dokopoulos: '**Influence Of Earth Stratification on Overhead Power Transmission Line Impedances. A Finite Element Approach**', *Proceedings of the MedPower 2002 Conference*, November 4-6, 2002, Athens, Greece, Pages 6.
4. B. Nilsson, P. Dokopoulos, G. Papagiannis, D. Tampakis, G. Bianconi, G. Fabozzi: '**A PLC-Based Electrical Energy Consumption Management System. Preliminary Field Test Results**', *Proceedings of the 7th International Symposium on Powerline Communications,* vol. 1, pp. 10-15, Kyoto Japan, 26-28 March 2003.
5. G. K. Papagiannis, D. A. Tsiamitros, G. T. Andreou, D. P. Labridis, P. S. Dokopoulos: '**Earth Return Path Impedances Of Underground Cables For The Multi-Layer Case- A Finite Element Approach**' , *PowerTech Conference Proceedings, 2003 IEEE Bologna,* 23-26 June 2003 Page(s): 7 pp. Vol.3 , doi: 10.1109/PTC.2003.1304514.
6. G. T. Andreou, D. P. Labridis, G. K. Papagiannis: '**Modeling of low voltage distribution cables for powerline communications**', *PowerTech Conference Proceedings, 2003 IEEE Bologna,* 23-26 June 2003 Pages: 6, Vol.2, doi:10.1109/PTC.2003.1304320.4.3.7.
7. D. A. Tsiamitros, N. Lettas, G. K. Papagiannis, D. Tampakis: '**A PLC-Based Energy Consumption Management System. Field Tests and Simulation Results**', *Proceedings of the 38th Universities Power Engineering Conference (UPEC)*, 1-3 September 2003, Thessaloniki, Greece, Vol. 2. pp. 417-420.
8. G. Papagiannis, D. Tsiamitros, K. Gouramanis, G. Andreou, P. Dokopoulos: '**A PLC Based Energy Consumption Management System. Pilot Installation Field Tests and Simulation Results**', *Proceedings of the 8th International Symposium on Powerline Communications*, Zaragoza, Spain, March 30-April 2, 2004, pages 6.
9. G. Papagiannis, K. Gouramanis, T. Papadopoulos, K. Papadopoulos, P. Dokopoulos : '**A PLC Based Energy Consumption Management System – Performance Analysis Of Overhead Lines And Underground Cables: Measurements And Simulation**', *Proceedings of the MedPower 2004 Conference*, Lemesos, Cyprus, November 14-17, 2004, pages 7.
10. A. Dagoumas, N. Lettas, G. Papagiannis, P. Dokopoulos: '**Economic And Environmental Impacts From The Implementation Of An Energy Consumption Management System At The European Level** ', *Proceedings of the MedPower 2004 Conference,* Lemesos, Cyprus, November 14-17, 2004, Pages 9.
11. D.A. Tsiamitros, G.K. Papagiannis, P.S. Dokopoulos: '**Earth Return Path Impedances Of Underground Cables For The Two-Layer Earth Case**', *Proceedings of the MedPower 2004 Conference*, Lemesos, Cyprus, November 14-17, 2004, Pages 8.
12. D.A. Tsiamitros, G.C. Christoforidis, G.K. Papagiannis, D.P. Labridis, P.S. Dokopoulos ' **A Novel Method For The Calculation Of Self And Mutual Impedances Of Overhead Conductors And Pipelines Buried In Two-Layer Soils**', *Proceedings of the MedPower 2004 Conference*, Lemesos, Cyprus, November 14-17, 2004, Pages 7.
13. N. Lettas, A. Dagoumas, G. Papagiannis, P. Dokopoulos, A. Zafirakis, S. Fachouridis, K. Manousaridis: '**Distributed Generation From Small Hydro Plants. A Case Study Of The Impacts On The Power Distribution Network**', *Proceedings of the MedPower 2004 Conference*, Lemesos, Cyprus, November 14-17, 2004, Pages 7.
14. N. Lettas, A. Dagoumas, G. Papagiannis, P. Dokopoulos, A. Zafirakis, S. Fachouridis, K. Manousaridis: '**Maximizing distributed generation capacity of small hydro plants in a distribution network**', *Proceedings of the Athens CIGRE Symposium, 'Power Systems with Dispersed Generation*', 16-20 April, 2005, Athens, Greece, Pages 8.
15. D.A. Tsiamitros, G.K. Papagiannis, P.S. Dokopoulos: '**Equivalent Resistivity Approximation of Two-Layer Earth Structures For Earth Return Impedance Calculations**', *PowerTech Conference Proceedings, 2005 IEEE St. Petersburg*, 26-30 June, 2005, Pages 7, doi: 10.1109/PTC.2005.4524626.
16. G.K. Papagiannis, T.A. Papadopoulos, C.D. Dovas, D.A. Tsiamitros, P.S. Dokopoulos: '**A**

**PLC-Based Energy Consumption Management System. PowerLine Performance Analysis: Field Tests and Simulation Results**', *PowerTech Conference Proceedings, 2005 IEEE St. Petersburg*, 26-30 June, 2005, Pages 7, doi: 10.1109/PTC.2005.4524631.

17. N. Lettas, A. Dagoumas, G. Papagiannis, P. Dokopoulos, A. Zafirakis, S. Fachouridis, K. Manousaridis: '**A Case Study of the Impacts of Small Hydro Power Plants on the Power Distribution Network with the Combination of On Load Tap Changers**', *PowerTech Conference Proceedings, 2005 IEEE St. Petersburg*, 26-30 June, 2005, Pages 7, doi: 10.1109/PTC.2005.4524627.
18. A. Dagoumas, N. Lettas, K. Tomaras, G. Papagiannis, P. Dokopoulos, A. Zafirakis, S. Fachouridis, K. Manousaridis: '**Transient Analysis of Small Hydro Generators in a Network - Connected and islanded operational mode** ',*International Conference on Future Power Systems*, November 2005, Amsterdam, Pages 6, doi: 10.1109/FPS.2005.204255.
19. A. Dagoumas, A. Marinopoulos, G. Papagiannis, P. Dokopoulos, '**Simulation of Small Hydro Generators in Islanding Operation in weak Distribution Networks',** XVII *International Conference on Electrical Machines ICEM 2006*, September 2006, Chania, Greece, Pages 6.
20. T. A. Papadopoulos, C.G. Kaloudas, G.K. Papagiannis, '**A Multipath Channel Model for PLC Systems based on Nodal Method and Modal Analysis**' *IEEE - ISPLC Conference 2007*, Pisa, Italy, 26-28 March, 2007, pages 6, doi: 10.1109/ISPLC.2007.371137.
21. T.A. Papadopoulos, B.D. Batalas, A. Radis, G.K. Papagiannis, '**Medium Voltage Network PLC Modeling and Signal Propagation Analysis**' *IEEE - ISPLC Conference 2007*, Pisa, Italy, 26-28 March, 2007, pages 6, doi: 10.1109/ISPLC.2007.371138.
22. T.A. Papadopoulos, G.C. Argyropoulos, B.D. Sarantinos, G.K. Papagiannis, '**Analysis of Indoor PLC Networks: Laboratory Tests and Simulation Results',** *PowerTech 2007 IEEE Lausanne*, Lausanne, Switzerland, July 1-5, 2007, pages 7, doi: 10.1109/PCT.2007.4538613.
23. T.A. Papadopoulos, G.K. Papagiannis, '**Influence of Earth Permittivity on Overhead Transmission Line Earth-Return Impedances**', *PowerTech 2007 IEEE Lausanne,* Lausanne, Switzerland, July 1-5, 2007, pages 7, doi: 10.1109/PCT.2007.4538416.
24. T.A. Papadopoulos, G.K. Papagiannis, D.P. Labridis, '**Wave Propagation Characteristics of Overhead Conductors above Imperfect Stratified Earth for a Wide Frequency Range**', 13th IEEE Conference on Electromagnetic Field Computation CEFC 2008, May 11 – 15, 2008, Athens, Greece, pages 4.
25. V.N. Katsanou, G.K. Papagiannis, '**Comparison of substation grounding system design methods using a FEM approach'**, *Proceedings of the MedPower 2008 Conference*, Thessaloniki, Greece, November 2-5, 2008, Pages 7.
26. P.N. Papadopoulos, A.G. Marinopoulos, G.K. Papagiannis, '**PEM Fuel Cell model in the Simulation of a Distributed Generation Network**', *Proceedings of the MedPower 2008 Conference*, Thessaloniki, Greece, November 2-5, 2008, Pages 6.
27. C.G. Kaloudas, T.A. Papadopoulos, G.K. Papagiannis, '**Transient Performance of Overhead Transmission Lines above Stratified Earth of Varying Permittivity'**, *Proceedings of the MedPower 2008 Conference*, Thessaloniki, Greece, November 2-5, 2008, Pages 6.
28. I.P. Panapakidis, G.K. Papagiannis, '**Evaluation of a supply side management and a demand side management policy implemented in the Greek electric sector**', *Proceedings of the MedPower 2008 Conference*, Thessaloniki, Greece, November 2-5, 2008, Pages 6.
29. T.A. Papadopoulos, D.A. Tsiamitros, G.K. Papagiannis, '**Analysis of the propagation characteristics of buried cables in imperfect earth',** *PowerTech 2009 IEEE Bucharest,* Bucharest , Romania, June 28 – July 2, 2009, Pages 8, doi: 10.1109/PTC.2009.5281842.
30. P.N. Papadopoulos, A.G. Marinopoulos, G.K. Papagiannis, '**Dynamic Modelling of a grid-connected PEM Fuel Cell in a Distributed Generation Network'**, *PowerTech 2009 IEEE*

*Bucharest,* Bucharest , Romania, June 28 – July 2, 2009, Pages 8, doi: 10.1109/PTC.2009.5281846.
31. V.N. Katsanou, G.K. Papagiannis, '**Substation grounding system resistance calculations using a FEM approach'**, *PowerTech 2009 IEEE Bucharest,* Bucharest , Romania, June 28 – July 2, 2009, Pages 6, doi: 10.1109/PTC.2009.5282044.
32. T.A. Papadopoulos, D.A. Tsiamitros, G.K. Papagiannis, '**Modal propagation characteristics of underground power cable systems'**, *Proceedings of the 44th International Universities Power Engineering Conference (UPEC)*, Glasgow, Scotland, September 1-4, 2009, Pages 5.
33. D.A. Tsiamitros, T.A. Papadopoulos, G.K. Papagiannis, **'Modeling of gas insulated lines buried in single- and in two-layer earth'**, *Proceedings of the 44th International Universities Power Engineering Conference (UPEC)*, Glasgow, Scotland, September 1-4, 2009, Pages 5.
34. Ch. G. Kaloudas, T.A. Papadopoulos, G.K. Papagiannis, "**Spectrum Analysis of transient Responses of Overhead Transmission Lines**", *45th International Universities Power Engineering Conference (UPEC)*, Cardiff, Wales, 31 August - 3 September, 2010.
35. T.A. Papadopoulos, A. I. Chrysochos, G.K. Papagiannis, "**Comparison of Earth Return Approaches on Modeling of Underground Cables**", *45th International Universities Power Engineering Conference (UPEC)*, Cardiff, Wales, 31 August - 3 September, 2010.
36. P. N. Papadopoulos, Ch. G. Kaloudas, T. A. Papadopoulos, G. D. Metaxas, G. K. Papagiannis, "**Magnetizing inrush current effects on large transformer arrangements**", *MedPower10 Conference*, Agia Napa, Cyprus, November 7-10, 2010.
37. Ch. G. Kaloudas, P. N. Papadopoulos, T. A. Papadopoulos, A. G. Marinopoulos, G. K. Papagiannis, "**Short-Circuit Analysis of a Power Plant Generator and Comparative Study of IEC, ANSI and Dynamic Simulation**", *MedPower10 Conference*, Agia Napa, Cyprus, November 7-10, 2010.
38. M. Horner, G. C. Christoforidis, G. K. Papagiannis, T. A. Papadopoulos, "**USE: Efficiency: A First Level Audit Analysisof Selected University Buildings from 9 EU Countries**", *3rd International Scientific "Energy and Climate Change" Conference*, Athens, Greece, October 7-8, 2010.
39. T. A. Papadopoulos, E. Topriska, G. K. Papagiannis, G. C. Christoforidis, "**Electrical Energy Consumption Analysis in Tertiary Buildings**", *3rd International Conference on Renewable Energy Sources & Energy Efficiency*, Nicosia, Cyprus, May 19-20, 2011.
40. G. C. Christoforidis, G. K. Papagiannis, T. A. Papadopoulos, S. McKay, "**Identifying Barriers preventing the Widespread of Wind Power in Europe - The GP-WIND Project**", *3rd International Conference on Renewable Energy Sources & Energy Efficiency*, Nicosia, Cyprus, May 19-20, 2011.
41. K. V. Gouramanis, Ch. G. Kaloudas, T. A. Papadopoulos, G. K. Papagiannis, K. Stasinos "**Sheath Voltage Calculations in Long Medium Voltage Power Cables**", *PowerTech, 2011 IEEE Trondheim*, Trondheim, Norway, June 19-23, 2011.
42. T. A. Papadopoulos, Ch. G. Kaloudas, P. N. Papadopoulos, A. G. Marinopoulos, G. K. Papagiannis "**Static and Dynamic Calculation of Short-Circuit Currents in Synchronous Generators**", *International Conference on Power Systems Transients - IPST*, Delft, The Netherlands, June 14-17, 2011.
43. Ch. G. Kaloudas, T. A. Papadopoulos, K. V. Gouramanis, K. Stasinos, G. K. Papagiannis, "**Simulation of Switching and Lightning Transients in Parallel Single-Core Underground Cables**", δεκτό για παρουσίαση στο *46th International Universities Power Engineering Conference (UPEC)*, Soest, Germany, September 5 - 8, 2011.
44. A. I. Chrysochos, T. A. Papadopoulos, G. K. Papagiannis, "**Improved Time-Domain Modeling of Underground Cables**", *46th International Universities Power Engineering Conference (UPEC)*, Soest, Germany, September 5 - 8, 2011.
45. P. N. Papadopoulos, M. D. Chatzisideris, T. A. Papadopoulos, A. G. Marinopoulos, G. K. Papagiannis, "**Integration of Smart Grid Technologies in a MicroGrid with PV and FC units**", *46th International Universities Power Engineering Conference (UPEC)*, Soest,

Germany, September 5 - 8, 2011.
46. G. C. Christoforidis, K. Ch. Chatzisavvas, T. A. Papadopoulos, G. K. Papagiannis, "Identifying non-Technological Barriers to Wind Power: Local Communities", 9th International Conference on the European Energy Market, Florence, Italy, May 10 - 12, 2012.
47. A. I. Chrysochos, T. A. Papadopoulos, G. K. Papagiannis, "Field Measurements of a Medium-Voltage Single-Core Cable Lying on the Ground Surface", 47th International Universities Power Engineering Conference (UPEC), London Brunel, U.K., September 4 - 7, 2012.
48. P. N. Papadopoulos, T. A. Papadopoulos, G. K. Papagiannis, "Dynamic Modeling of a MicroGrid using Smart Grid Technologies", 47th International Universities Power Engineering Conference (UPEC), London Brunel, U.K., September 4 - 7, 2012.
49. A. I. Chrysochos, E. T. Makri, A. C. Dimou, T. A. Papadopoulos, G. K. Papagiannis, " An Investigation of the Performance of Underground Cable Installations in Operational and Fault Conditions", MedPower12 Conference, Cagliari, Italy, October 1-3, 2012.
50. T. A. Papadopoulos, G. C. Christoforidis, K. Ch. Chatzisavvas, G. K. Papagiannis, "Harmonic Level Measurements and Analysis at Higher Education Buildings", MedPower12 Conference, Cagliari, Italy, October 1-3, 2012.

**AWARDS**

- Conference paper 23 was awarded with the *Basil Papadias* award for the best student paper, presented at the IEEE PowerTech 07 Conference, Lausanne, Switzerland.
- Conference paper 45 was awarded with the best oral presentation award, presented at the 46th International Universities Power Engineering Conference (UPEC), Soest, Germany.