ANNEX 2: TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

Use-Project Acronym	ModVal
User-Project Title	Validation of PV models and PV simulator
Main-scientific field	Renewable Energy Sources
Specific-Discipline	Photovoltaic Models

Lead User of the Proposing Team:

Name	Dr.-Ing. Tatakis Emmanuel
Phone	+30 2610 996412, +30 2610 996415
E-mail	e.c.tatakis@ece.upatras.gr
Nationality	Greek
Organization name, web site and address	University of Patras, Department of Electrical and Computer Engineering, Laboratory of Electromechanical Energy Conversion, 265 00 Rio-Patras, Greece
Activity type and legal status* of Organization	Higher Education Institution
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	Nanakos Anastasios
Phone	+30 2610 996414, +30 6974739153
E-mail	tnanakos@ece.upatras.com
Nationality	Greek
Organization name, web site and address	University of Patras, Department of Electrical and Computer Engineering, Laboratory of Electromechanical Energy Conversion, 265 00 Rio-Patras, Greece
Activity type and legal status* of Organization	Higher Education Institution
Position in Organization	PhD Candidate

Additional Users in the Proposing Team:

Name	Perpinias Ioannis
Phone	+30 2610 996414, +30 6975862975

DERri
Distributed Energy Resources
Research Infrastructures

E-mail	jperpin_21@hotmail.com
Nationality	Greek
Organization name, web site and address	University of Patras, Department of Electrical and Computer Engineering, Laboratory of Electromechanical Energy Conversion, 265 00 Rio-Patras, Greece
Activity type and legal status* of Organization	Higher Education Institution
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)

(Repeat for all Users)

Date of submission	30 September 2010
Re-submission	YES_______ NO___X____
Proposed Host TA Facility	AIT - Wien (Austria), IWES - Kassel (Germany)
Starting date (proposed)	End of January

Summary of proposed research (about ½ page)

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

The Laboratory of Electromechanical Energy Conversion, Department of Electrical and Computer Engineering, University of Patras has a great experience in the analysis, design and development of power converters for PV applications. In order to assist this activity, a model of PV module for use in the Simulink/Matlab program, a DG-PV model for electrical system studies and a PV Simulator has been developed.

Regarding our models, we need to check their accuracy and effectiveness, through experimental measurements. On the other hand, we want to compare the operation of our PV Simulator with commercial PV Simulator, both for the static behavior but mainly for the dynamic behavior.

So, the target of the proposed research is to conduct measurements on an equipped laboratory in order to validate the developed models and as well as the behavior of the PV simulator.

State-of-the-Art (about 1 ½ page)

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

During last years the research conducted in the Laboratory of Electromechanical Energy Conversion, University of Patras is related to issues which have to do with Photovoltaic systems [1]-[8]. In the frame of diploma and doctoral thesis as well as various research programs PV models, a DG-PV model for electrical system studies and PV simulator has been developed.

In order to simulate a PV system a mathematical model should be selected. The model should be accurate but simple, so as to avoid extensive duration of the simulation and complexity. Moreover, its parameters should be easily identified and modified, to simulate various PV modules. There has been several simulation models developed in Matlab environment [9]-[15]. Most of them are based on a code developed in the Matlab editor, use a "unit" I-V curve that can be scaled to any arbitrary system size, or use measured data. However these approaches don't offer great flexibility. On the other hand there are two mathematical models that describe a photovoltaic array, the Parametric model and the Interpolation model. In order to model the output characteristics of a PV module we chose to use the Interpolation model. Unlike the Parametric model that needs physical PV parameters, the Interpolation model uses the manufacturer's data and gives the ability to simulate different types and sizes of arrays under any irradiation and temperature, in an easy way.

Detailed system studies have to be carried out in order to predict DG-PV affection to system response under critical conditions. This task calls for analytical DG-PV models suitable for Power system studies [16]-[20]. Although such models are available for WFG, there have not been developed similar models for DG-PV systems yet, due to their relatively low penetration level. Thus, DG-PV generation is usually modeled as constant power source (with solar radiation level being parameter), while for larger (centralized) PV systems a reactive power injection is also considered, in an amount generally proportional to the active power generation (based on measurements in already installed systems). In these models there is a current limit of 1.2 times the nominal inverter current, enforced by its control loop. The above mentioned models are suitable for static system studies (load flow calculations), as they can predict with accuracy the energy production and the operation point of the PV system under steady state or long term transient conditions (i.e. solar radiation changes). On the other hand, these models can not deal with fast transient conditions. The whole work becomes more complicated since DG-PV systems are characterized by numerous alternative solutions in the inverter stage, demanding different modeling development or at least the construction of representative model platforms based on a provisional inverter categorization. Taking for granted that the detailed description based on the inverter switching operation is not acceptable for load flow – based studies, it is obvious that an analytical DG-PV model is necessary in order to examine systems with large photovoltaic penetration.

Among related papers in international bibliography [21]-[26], different systems that assimilate the output characteristics of photovoltaic generators are presented. In all these systems we can distinguish four basic aspects of their operation. First of all is the theoretical model that reproduces the characteristic V-I curve. The dominant models are the parametric and the interpolation model. The parametric model is very accurate but it is used when all the parameters are known. The interpolation model needs only three specific points of the real curve to reproduce the whole curve. Secondly is the type of the control implementation. This control is responsible to force the hardware to act as a PV generator. In some papers the control is implemented by a microcontroller, in others by a personal computer or a special real time digital simulator (RTDS) that combines hardware and software. The third aspect that a simulator includes is the hardware that supplies the power as it is generated from the sun. In most papers the researchers propose custom made buck or buck-boost converters in order to generate PV characteristic curves. In work the simulator is based on an active power load without power consumption. On the other hand in paper, the basis is a RTDS flexible real – time simulator. Power system networks are created on the RTDS by arranging electrical components from the model libraries. Analog signals can be interfaced between the RTDS and the external equipments via analog input ports for real time simulation. The fourth and final part of a PV simulator consists of the user interface the extra features and the representation manner of the results and graphs.

References

List relevant References

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

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

The Laboratory of Electromechanical Energy Conversion, Department of Electrical and Computer Engineering, University of Patras has more than 10 years experience in matters related to power converters for renewable energy sources (wind turbines, photovoltaic (PV)). The last 5 years under the guidance and supervision of the Associate Professor Dr.-Ing. Emmanuel Tatakis, the research has focused on converters for PV systems interconnected to the grid and especially on a new technology, the so called AC-PV modules.

To assist the design and development of such converters it is necessary to use some helping tools, such as PV models for use in circuit analysis programs (Simulink/Matlab,Pspice) and equivalent system models for use in electrical analysis network programs PV Simulators. For this reason the LEMEC research team has developed such tools namely:

- a model of PV module for use in the Simulink/Matlab program
- a DG-PV model for electrical system studies
- a PV Simulator

Concerning the models in order to assist effectively the analysis and development of converters, they should be as simple as possible and provide a good accuracy. On the other hand, the PV simulator has to accurately reproduce both the dynamic and static behavior of a real PV array. Hence, in few words the target of the proposed research is to conduct measurements on an equipped laboratory in order to validate the developed models and as well as the behavior of the PV simulator.

Hereafter, we will present more analytically the two models and the PV simulator as well as the measurements that we have the intention to realize in one of the specified laboratories of the TA infrastructures.

a) a model of PV module for use in the Simulink/Matlab program

Generally speaking, simulation verifies the theoretical estimations or calculations, aids in tracking problems that may occur and affirms the right operation of a system. Researchers can predict the behavior of the PV system, study the stability, develop software that may help in the planning and designing of PV systems, evaluate the MPPT algorithms and the interaction of PV systems with other systems. Among other circuit simulators Simulink offers a lot of advantages to simulate large power systems, the main of which are the graphical interface, numerical capabilities, as well as functions and blocksets for power electronic circuits and systems built into Simulink. Moreover, MatLab/Simulink software is common in academic circles.

In order to simulate a PV system a mathematical model should be selected. The model should be accurate but simple, so as to avoid extensive duration of the simulation and complexity. Moreover, its parameters should be easily identified and modified, to simulate various PV modules. In our laboratory a Simulink/Matlab based model of a PV module that can be used to study the effect of temperature and insolation levels on large PV arrays.This PV model is suitable to be incorporated in the simulation of large scale power distribution systems. It is simple, accurate and its parameters can be easily modified as they are given by PV manufacturer data sheets. Moreover, the operation of series and parallel connected modules is demonstrated for different insolation and temperature conditions.

b) a DG-PV model for electrical system studies

Nowadays, the large DG-PV integration in the electrical power systems (EPSs) calls for detailed system studies to be carried out in order to predict DG-PV affection to system response under critical conditions. So analytical DG-PV models should be developed. Although such models are available for Wind Farm Generation (WFG), there have not been developed similar models for DG-PV systems yet, due to their relatively low penetration level. Thus, DG-PV generation is usually modeled as constant power source (with solar radiation level being parameter), while for larger (centralized) PV systems a reactive power injection is also considered, in an amount generally proportional to the active power generation (based on measurements in already installed systems). In these models there is a current limit of 1.2 times the nominal inverter current, enforced by its control loop. The above mentioned models are suitable for static system studies but they can't deal with fast transient conditions. The whole work becomes more complicated since DG-PV systems are characterized by numerous alternative solutions in the inverter stage, demanding different modeling development or at least the construction of representative model platforms based on a provisional inverter categorization. Taking for granted that the detailed description based on the inverter switching operation is not acceptable for load flow – based studies, it is obvious that an analytical DG-PV model is necessary in order to examine systems with large photovoltaic penetration.

An initial effort has been done by LEMEC research team, presenting an analytical DG-PV model for system studies based on the expression of the equivalent load resistance of the PV generator (R_{PV}) as a function of the system conditions. This model is for the case of DG-PV generation driven by a Current control SPWM-VSI, which is the most common case for commercial applications.

c) a PV Simulator

For the development of converters and the control of their operation, is required the use of PV Simulators. Such a simulator has been developed by LEMEC research team. Our system has the ability to generate the current-voltage curves of photovoltaic modules under any desirable insolation and temperature conditions. The system is also capable of integrating any maximum power point tracking algorithm under a unified control. The simulator's aim is the introduction of a faster, spherical and more effective approach in experimental investigation of photovoltaic systems, either in standalone or grid connected applications, independently from the atmospheric conditions. Towards this aim, the use of a DC power supply, controlled through a data acquisition card by appropriate algorithms, is proposed. These algorithms are implemented on a personal computer. Special effort was given in the development of a simplified user interface that monitors and controls the entire system offering effortless and faster conclusions.

Regarding our models, we need to check their accuracy and effectiveness, through experimental measurements. On the other hand, we want to compare the operation of our PV Simulator with commercial PV Simulator, both for the static behavior but mainly for the dynamic behavior. The order in which the experiments will be conducted is as follows. First, we will deal with the model of matlab, then with the PV Simulator and finally with the a DG-PV model for electrical system studies.

Then, with regard to equipment requirements we have to notice the following:

- As concerning the matlab model, we need to take measurements via an automated system in a PV panel in order to compare experimental results with simulation results. We also need to have access to a PV array, so that we take measurements in several cases of partially shaded array.
- For the DG-PV model for electrical system studies, we need a PV Simulator or a PV array,

an inverter and a grid simulator. The inverter can be commercial or made by TA team, otherwise we will use an inverter that has been constructed in LEMEC. Finally, the grid simulator will be used for voltage fluctuations and short circuits.

- Finally in order to evaluate the performances of our simulator, we should have a commercial simulator to measure each static and dynamic behavior and compare with our simulator characteristics.

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

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

According on our research on previously published works the DG-PV model for electrical system studies as well as the dynamic behavior of PV simulator are innovative and the proposed research will help us to validate our model and publish our work on scientific journals.

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

Specify the type of TA infrastructure (e.g. distributed generation simulator; domotic house; etc.) and if possible which one of the 13 TA Infrastructures in DERri may better serve the scope of the proposed research. Justifications should be provided on the grounds of the test set-up, testing method, equipment, past experience in relevant subject, etc. State whether the TA User team intends to deliver to the premises of the TA Infrastructure parts or components to be tested at the TA User's expense and responsibility, or to cover the whole or part of the construction/adaptation cost of the specimens to be tested.

The type of TA infrastructure has been presented in previous paragraphs. By examining the characteristics of each TA infrastructure, we believe that the TA infrastructure of AIT in Vienna meets better our needs because they can provide us all the necessary equipment required to perform our measurements. Moreover, we believe that the TA infrastructure of IWES in Kassel is adequate for our measurements. As mentioned previously, the User team has a great experience in the design and measurements on power converters. In particular the last 5 years research has focused on converters for PV and especially in a new technology that are the AC PV modules. On this basis our TA User team has a significant interest in this research field.

Regarding the construction/adaptation cost of the specimens to be tested, we would like the TA infrastructure to cover all costs totally.

Synergy with ongoing research (about ½ page)

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

According to our knowledge, we know that in Greece, in the centre of renewable energy sources (CRES), a PV simulator similar to our one has been developed. We are in contact and in full collaboration with the research team of CRES that has developed this simulator and we will notify the results of measurements and the conclusions that will occur.

On the other hand, the DG-PV model for electrical system studies as mentioned above, is a new research area and there are not bibliography references on this subject.

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.

Our goal is to infer important conclusions from this project and publish our work in international scientific journals as well as to present it at international conferences.

Time schedule (about ½ page)

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

As mentioned previously, our goal is to make measurements in three different areas: the PV model in the Simulink/Matlab, the PV simulator and the_DG-PV model for electrical system studies. We believe that the time required for measurements in the PV model of Matlab and the PV simulator is 15 days. The target starting date would be the late January or early February 2011. For the DG-PV model for electrical system studies, we consider that we need 15 days and the starting date would be the Mid-June 2011. The 15 days of June may also be used for additional measurements in the PV model of Matlab and the PV simulator. This will occur or not depending on the evaluation of the results of the previews period.

-It has to be noticed that the estimated cost per day for subsistence of each member of the User team will be 150-200€, while the cost of air tickets (arrival and departure) will be at around 300€ per person. Also, they will travel only the two members of the team.

Description of the proposing team (as long as needed)

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

<u>Lead user of team: Tatakis Emmanuel</u>

Dr.-Ing. Emmanuel C. Tatakis received the Electrical Engineering Diploma from the University of Patras, Greece, in 1981, and the Ph.D. degree in Applied Sciences from the University of Brussels, Belgium, in 1989. He joined, as a Lecturer, the University of Patras, Department of Electrical and Computer Engineering, in 1993, where he is currently an Associate Professor (since 2006). He has more than fifteen (15) years teaching experience and more than twenty five (25) years research experience in subjects related to Power Electronics and Electrical Machines.

Since 1993, he is teaching Power Electronics (three courses), he is involved in Electrical Machines Laboratory Exercises and he is directing several diploma theses (more than 90 until now) and PhD theses (three have been already accomplished, three are in full progress). He has also participated in many research projects (thirteen until now, five as Leader) supported by European, National or Private founds.

His research interests include the analysis, modeling, simulation and construction of power electronics converters for various applications such as Switch Mode Power Supplies, Resonant Converters, Power Factor Correction, Electric Drive Systems, Electric and Hybrid Vehicles, Renewable Energy Systems (photovoltaic and Wind), Space Applications, Educational Methods in Electrical Machines and Power Electronics. His research is focusing on the analysis, design and control of power electronics converters in order to achieve the optimal operation, concerning the efficiency and the power density, the minimization of the harmonic content as well as the maximization of the power factor. He is also specialized in the analysis, modeling and simulation of power semiconductor devices, high frequency transformers and other passive devices.

He is the author and co-author of fifteen (15) international and four (4) national journal publications, as well as of sixty-nine (69) international conference papers and twenty-two (22) research program reports. Until now his published work is referred by more than one hundred forty five (145) research teams.

Dr.-Ing. E. Tatakis is member of the European Power Electronics Association, the Société Royale Belge des Electriciens and the Technical Chamber of Greece.

Member of team: Nanakos Anastasios

Mr Nanakos Anastasios was born in 1981. He studied at the University of Patras from 1999 to 2005 in the Department of Electrical and Computer Engineering and he received his diploma in May 2005. From the September 2005 he is a PhD student at the University of Patras, Department of Electrical and Computer Engineering, Laboratory of Electromechanical Energy Conversion. His research interests include Power Electronics, Renewable Energy Sources, Photovoltaics, Inverter, AC-PV Modules. He participated in two research programs dealing with PV applications and is author of three conference papers.

Member of team: Perpinias Ioannis

Mr Perpinias Ioannis was born in 1986. He studied at the National Technical University of Athens from 2004 to 2009 in the Department of Electrical and Computer Engineering and he received his diploma in November 2009 with the grade 7.58. From the November 2009 he is a PhD student at the University of Patras, Department of Electrical and Computer Engineering, Laboratory of Electromechanical Energy Conversion. His research interests are the power converters for renewable energy sources and the operation of electric microgrids. He speaks English and French.