APPENDIX 2: Template for proposal under DERri

User-Project Proposal:

Use-Project Acronym	DEMSPV
User-Project Title	**Dem**onstrator for **S**mart **P**hotovoltaic **S**ystem
Main-scientific field	Power Electronics for Photovoltaics
Specific-Discipline	Microinverters

Lead User of the Proposing Team:

Name	Alex Masolin
Phone	+32 16 328561, +32 478 683800
E-mail	Alex.masolin@esat.kuleuven.be
Nationality	Italian
Organization name, web site and address	KU Leuven, ESAT/Electa
Activity type and legal status* of Organization	Public research organization (2)
Position in Organization	Postdoctoral 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)

Additional Users in the Proposing Team:

Name	Urmimala Chatterjee
Phone	
E-mail	Urmimala.Chatterjee@esat.kuleuven.be
Nationality	Indian
Organization name, web site and address	KU Leuven, ESAT/Electa
Activity type and legal status* of Organization	Public research organization (2)
Position in Organization	Ph.D. student

DERri
Distributed Energy Resources
Research Infrastructures

Name	Buvana Lefevre (*)
Phone	
E-mail	Buvana.lefevre@esat.kuleuven.be
Nationality	Indian
Organization name, web site and address	KU Leuven, ESAT/Electa
Activity type and legal status* of Organization	Public research organization (2)
Position in Organization	Ph.D. student

(*) She won't be able to travel to Austria due to maternity leave.

Date of submission	12.07.2013
Re-submission	YES_______ NO__X_____
Proposed Host TA Facility	AIT - Austrian Institute of Technology, Österreichisches Forschungs- und Prüfzentrum Arsenal Ges.m.b.H.
Starting date (proposed)	Mid november 2013

Summary of proposed research (about ½ page)

The ESAT/Electa group at KU Leuven is currently studying smart photovoltaic systems in the scope of renewable energy technologies research. Consequently, we are in the process of developing experimental platforms that require a host of components including maximum power point trackers (MPPTs) and module integrated converters (MICs). Instead of using one central converter MICs are used to minimize power mismatch losses between strings of the PV panel and thus, to increase overall efficiency.

1. The MICs we are developing is home-designed and implements a new boost topology. Since a MIC's efficiency varies with power and voltage, its efficiency map is often valuable. It would be nice to have the possibility to measure efficiency map also in function of operating temperature. The insight one gains from these efficiency maps facilitates improvement of the home-designed converter's performance and enable a detailed power loss analysis. These maps will be benchmarked against state-of-the-art commercially-available MIC.
2. Each MIC uses a MPPT for dynamic tracking of the operating point. Improvements in the dynamic tracking efficiency of a MPPT in turn should improve the overall conversion efficiency of the converter-tracker duo.

State-of-the-Art (about 1 ½ page)

In general, the proposed work is to test power electronics equipment. Therefore, all available knowledge for testing such products can be used and shall be applied. PV micro-inverters with MPPT are in the focus of this project. Especially within AIT there exists long term experience in testing grid connected DC-AC inverters.

For grid connected PV systems, the converter is playing a crucial interfacing role, mainly for two reasons. First, the low DC voltage generated by the module must be amplified to a stable sufficient level and then inverted to the AC voltage in the grid. Second, the power delivered from the modules is very sensitive to the point of operation, and the converter should therefore incorporate a function for tracking the Maximum Power Point (MPP).

Today, for grid-connected photovoltaic applications, central and string inverters are the most commonly used configurations. However in these cases, module mismatches or shading effects will cause significant power losses. Therefore an alternative approach has been proposed where every module is connected to its own converter (MIC) stage which operates at its own maximum power point. This circuit is preferably located as close as possible to the panel, likely at the backside in outdoor conditions. Additional advantages of this approach, besides enhanced energy yield, are improved safety, more monitoring capabilities, and improved modularity and flexible system design.

More importantly, the market for MIC, started only in 2010 in the U.S., with as of today a handful of manufacturers, whereas in Europe the market is yet to lift off. The broad variety of topologies and designs, as well as the substantial optimization potential, clearly show that this is a market still in its infancy. Nevertheless, it is believed micro-inverters have a huge growth potential because of three reasons: first, micro-inverters are especially suited for building-integrated applications, where complex shadowing conditions reign, a situation where micro-inverters have a clear advantage in comparison with the commonly used string-inverters; second, the plug-and-play character make micro-inverters very appealing to many customers; third, and not least, the small size and high numbers allow huge cost reductions through integration into the PV module, specially adapted power electronics circuits, application specific integrated circuits (ASICs) and mass-production, more than is possible with larger sized inverters.

Hence, there is a clear opportunity for new entrants to take part of this promising market.

It is possible to have a module integrated dc-dc converters which converts the variable current from the PV module to match the common output dc-voltage shared with other modules in a series string connection. The combined string output is used by a larger string or central inverter to deliver ac power to the grid. First attempts in this direction are presently appearing on the market (SolarMagic, SolarEdge, Enphase Energy, Enecsys , PowerONE).

One of these commercially-available device will be used as benchmark. Its maximum efficiency is claimed to be 99.5% (European Weighted Efficiency 98.8%). The efficiency map (efficiency versus power/voltage) is not available. It will be part of this project to provide this map (this device will be provided by KU Leuven).

The measurement of the accuracy of the MPP control algorithm can be done in accordance with the test procedure of DC-AC grid tied inverters. The efficiency of the controller can be estimated for controlled input and load conditions. These conditions found in literature or standards most likely reflect real world conditions and at the least will be a benchmark for controller evaluation.

References

- U. Chatterjee & J. Driesen, “Intra-Module DC-DC Converter: Topology Selection and Analysis”, KU Leuven, Belgium
- EN 50530_2010 Overall Efficiency of PV Inverters
- IEC 61683, Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- Ropp, M., et al., "A test protocol to enable comparative evaluation of maximum power point trackers under both static and dynamic irradiance," *37th IEEE Photovoltaic Specialists Conference (PVSC),* June 2011.
- Kasper, M., et al., "Classification and comparative evaluation of PV panel integrated DC-DC converter concepts," *Power Electronics and Motion Control Conference (EPE/PEMC), 2012 15th International* , 4-6 Sept. 2012.
- Trujillo Rodriguez, C., et al., "Reconfigurable Control Scheme for a PV Microinverter Working in Both Grid-Connected and Island Modes," *IEEE Transactions on Industrial Electronics*, April 2013
- SolarMagic: http://www.solarmagic.com/
- SolarEdge: http://www.solaredge.com/
- Enphase Energy: http://www.enphaseenergy.com/
- Enecsys: http://www.enecsys.com/
- Other internal documentation and reports is available after and NDA agreement or after internal IP protection workflow has been completed, i.e. after provisional application for patent is filed.

Synergy with ongoing research (about ½ page)

Module integrated or module mounted power electronic devices are becoming increasingly popular in the PV Balance-Of-System (BOS) components sector whereas the optimization of the conversion efficiency as well as Maximum Power Point Tracking MPPT is in the focus of R&D activities. A number of ongoing research projects are dealing with the development and research on small scale high performance power conversion units, like the EC FP6 project PV-MIPS (www.pvmips.org), and the Austrian national project IPOT (www.ipot-project.at) which deals with the improvement of the functionality of solar modules by integration of MPP trackers.

Generally, new products need to be tested to check the functionality and the specified features. Therefore, at KU Leuven research activities focus on the small-scale power electronics circuitry. It targets to build low power (<300W), small size (>250W/dm3) and cost effective power converter. This converter will be useful for renewable energy domain such as in PV modules where low power and efficient converter is required as interface. Moreover, major effort and resources are allocated to the development of efficient control algorithms.

The proposed project will suit perfectly in the framework of "Smart-PV" project (projects.imec.be/smartpv) funded by IWT – Flemish Agency for the Innovation in Science and Technology. One of the high-level objectives is to provide a new concept of MIC as enabler to increase the annual energy yield of a PV module of 100 KWh/KWp, under typical Belgian climate conditions.

Unfortunately, the infrastructure of the KU Leuven is only partially able to perform all the test required to characterize this innovative MIC. On the other hand, the solid know-how and up-to-date infrastructure of a renowned testing unit like AIT will fill this gap.

Dissemination – Exploitation of results (about ½ page)

Early results will be communicated at the first available plenary technical meeting of the SmartPV consortium. Consolidated results will be presented as well at the user committee meeting of the same project. Both these meetings will be hold in January 2014, at latest.

An internal presentation will be given to all the affiliate of our research group to report on the technical results as well as the capabilities of the host infrastructure.

Two publications in international peer-review journals are foreseen. The target is journals with Impact Factor higher than 4. The first article will deal with the description of the topology as well as simulation results of the potentiality of this circuit. A second publication will focus on actual measurements, e.g. efficiency vs. power and input voltage. These will be benchmarked with state-of-the-art commercial MICs. The host institution and the sponsors of DERri project will be acknowledged accordingly.

Furthermore, following the successful completion of the proposed tasks of testing and improving MPPT and MIC design, there is a common interest of both institutions to continue to collaborate together, even beyond the scope of DERri.

Finally, KU Leuven is currently in the process to protect Intellectual Property related to this new circuit topology, i.e. brand registration and patents. As soon as these will be granted, the hardware and software tested at AIT will be key in the IP portfolio of KU Leuven, which later will be transferred to Energyville. Energyville will be a knowledge center focused on green energy and energy technology, which at its start will host some 200 researchers (www.energyville.be). Potentially, the know-how built around this new circuit could lead the creation of a spin-off and/or licensing to a potential customer (see SmartPV User Committee members) in order to have commercial exploitation.

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

Photovoltaic (PV) power supplied to the utility grid is gaining more and more visibility, while the world's power demand is increasing. This is evident from the fact of setting the goal in Europe by the Solar Europe Industry as the aim to supply 12% of the electricity demand by PV power plant in 2020 target. PV industry focused on research and development of new materials in micro and nanoscale technology for solar cells and modules, different types of device structures, module design with the overall aim of improving system efficiency and reducing cost. Research on electronic components is also gaining more attention by realizing the need of higher energy yield in suboptimal locations. Recently, in low power PV generation systems a new energy conversion solution is becoming appealing. It consists in the integration of small converters DC to DC and DC to AC inside the PV panels used for solar energy harvesting. Today, we see also a trend to increase the switching frequency in order to reduce the size of the converter design paving the pathway to micro-converters for PV module.

Therefore, the proposed project aims:

1. to develop a distributed control scheme for a reconfigurable PV system
2. to evaluate the performance of home-designed MIC: measure dynamic performance, its efficiency map (efficiency versus power, voltage and – preferably – operating temperature), estimate converter losses and discuss possible improvements of the design
3. to evaluate the performance of the home-designed MIC in terms of Total Harmonic Distortion, conducted Electromagnetic interference (EMI) and Electromagnetic compatibility (EMC)

The efficiency map of converters would enable evaluation of control algorithms under various system operation conditions. Hence, both commercial and home-designed converters would be used to test the preliminary distributed controller. Further test of the single components of the MIC (power switch, passives, …) will enable an extensive power loss analysis.

Operation modes such as island operation, grid connected operation - possibly with a storage system - would be tested on the developed system. Various types of loads or load simulations are then required for this the follow-up test.

The above study shall be repeated with other commercial micro-converters as well, in the hope of the one hand to develop a generic controller that shall not only work for the specifications of the home-designed MIC but for any converter suitable for the application. On the other hand, to benchmark the capabilities of the proposed innovative topology and design with state-of-the-art components.

Moreover, since our MIC is designed to operate in very high frequency (≥ 500 kHz), it is desirable to have a thorough EMI/EMC testing. This is also necessary to measure filter capacitor response of the converter.

Furthermore, a parallel goal of the proposed project is to identify any technical problem and weak point of the developed MIC topology and MPPT scheme.

From the tests and feedback at the host institute, the possible insufficiencies in the controller-MIC system would be worked out and improved and, in case of enough allocation of resources, the performance of an improved distributed controller as well as a “MIC 2.0” design could be then re-evaluated at the host site. The full system will comprise solar panels, module integrated converters and maximum power point tracker. The system should ideally be connected to the grid or, at least, a grid simulator.

Conversely, in case that the above said objectives require more time than we currently estimate and thus render us unable to complete every one of them within the short span of the project, we would like to continue our collaboration with the host institute beyond the scope of DERri through bilateral agreement or through other consortia which they may be part of.

List of specification of the MIC under test:

Input voltage range: 10 – 30 V

Input current: 8 A

Output voltage: 120 V

Operating frequency: 500 kHz

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

Distributed power generation, with its gaining popularity, is highly relevant to solar energy production. Although solar energy is abundant, the limitations to the power availed is limited mainly due to its variable nature stemming from environmental conditions. So a combination of solar and grid energy is used up local loads close to the PV system premises. But the abundance of the solar energy is not exploited unless excess energy is somehow channeled to other loads. Hence, an interesting combination of grid, battery and local load could all be used for a PV generator to increase the consumption of solar energy.

The novel converter topology would support operation modes and several different types of loads.

Conventional control schemes become excessively complex and expensive in case of additional functionalities that the new system demands. Hence, less complicated, intelligent but efficient control scheme is required. Such a control scheme would firstly, bring the cost down; secondly, adapt better to the new system topology and hence be more efficient; and finally allow the system to be reconfigurable. Additionally, the proposed solutions would also feed in to the popularity of these systems.

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

The AIT - Austrian Institute of Technology, already performs a huge variety of different power electronics tests for the PV industry. Grid-tied inverters play an important role in the test lab. Therefore our choice would be that the work shall be done at AIT labs. The facilities at AIT would immensely help in the progress in building a smart PV experimental tool at KU Leuven.

The advantage is also that the necessary equipment is already available at AIT. For the testing the following equipment is necessary:

- Measurement devices
  - Power Analyzer, multiple power measurement channels
  - Multi Channel Digital storage oscilloscope
- Loads
  - 3 x RLC AC loads, continuously adjustable, 12kW, 21 kVAr
- Sources
  - AC source (3 phase and single phase)
  - DC source (3 string PV Array Simulator)
  - Public grid
- Components
  - Data monitoring of all electrical parameters
  - Data analyses software for MPPT efficiency and data analyses.

KU Leuven would largely benefit, in the research, from the performance and operational testing facilities of the same institute.

Support in the form of data analysis and follow-up after the experiments at AIT would enhance our knowledge and speed-up our progress in the project but more importantly would be of great help in understanding the work dynamics of AIT and pave the way for future collaborations.

Time schedule (about ½ page)

Start: Fall 2013

Duration (may maximum 2 weeks for testing in total): 2 weeks

Organization (one or two separate time slots): One slot

Dissemination plan (when results will be present): Journal papers and a paper for EUPVSEC 2014 will be submitted beginning 2014. Internal communication will be performed on the first time-slot available (no later than January 2014).

Description of the proposing team (as long as needed)

Alex Masolin, Ph.D. received his Bachelor Degree and Master Degree in Electronic Engineering from the University of Udine, Italy. In 2012, he received his PhD degree in Electronic Engineering from the KU Leuven, Belgium. PhD dissertation dealt with silicon solar cells wafering technology and it was pursued at imec, Belgium. Currently, he is a postdoctoral researcher at the department of Electrical Engineering at the KU Leuven, Belgium performing research on power switches, Smart PV modules and integration of renewable energies into the SmartGrids. He is also involved in the design of PV installation for the Energyville project.

Urmimala Chatterjee, M.Sc. has completed her B.Tech degree in Electronics Engineering from India. She achieved a Master of Science (MS) degree in Integrated Circuit Design from TUM-NTU. This is a joint degree program from Technical University Munich, Germany and Nanyang Technological University, Singapore. Her master thesis dealt with Thermal Modeling of Smart PV System from imec, Belgium. Currently, she pursuing her PhD degree in the department of Electrical engineering at the KU Leuven on innovative power electronics circuit design. She is actively involved by the 'Smart PV' project funded by IWT, the Flemish Agency for Innovation in Science and Technology.

Buvana Lefevre, M.Sc. is currently pursuing her doctoral studies at ESAT/Electa, KU Leuven in the scope of SmartPV. She hails from India where she obtained her Bachelor of Engineering in Electronics and Communication. She then worked as a research associate on optical networks in the Photonics group of Electrical Engineering department at the Indian Institute of Technology Madras, Chennai, India. She was a recipient of Erasmus Mundus scholarship for her Master of Science in Engineering with major in Photonics during which she worked on solar concentrators. Through the scholarships mobility programme she has worked with diverse international teams in the varied cultures of Sweden, Belgium and Scotland. She has also interned at imec, Belgium where she worked in the scope of SmartPV.