DERri
Distributed Energy Resources
Research Infrastructures

ANNEX 2: TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

Use-Project Acronym	DPDinv
User-Project Title	Determining the power dissipation in power stage inverters
Main-scientific field	Electronics system and modeling
Specific-Discipline	Renewable Energy

Lead User of the Proposing Team:

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Activity type and legal status* of Organization	Higher Education Institution
Position in Organization	PhD researcher and assistant 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:

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Activity type and legal status* of Organization	Higher Education Institution
Position in Organization	Professor Dr.

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

Additional Users in the Proposing Team:

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Activity type and legal status* of Organization	Higher Education Institution
Position in Organization	Electronics support

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

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Activity type and legal status* of Organization	Higher Education Institution
Position in Organization	Electronics support

* 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	20.02.2012
Re-submission	YES___ X ___ NO_____
Proposed Host TA Facility	AIT Austria
Starting date (proposed)	03.06.2012

Summary of proposed research (about ½ page)

The proposed project focuses on development of a modified method for determining the losses in MOSFET switching power output stage. It is known that many modern sources (such as PV systems inverters, DC motor controllers) use output inverters to convert the signal. During it's commutation, this type of inverters are classified according to their input-output converters: DC-DC, DC-AC inverters, etc.. To reduce losses, we offer development of a modified method for the analysis of losses in the output stage. The proposed method is a modification of the known method [1] to determine the baseline efficiency of switching operated output transistors. The proposed approach is widely applied in all renewable energetic sources. The idea stems from the high output losses in switching transistor and cause serious interest in the production of switching inverter. The development of this project offers the precision of the reasons for these losses in the output MOSFET transistors. Proper selection and knowing the exact parameters of the output switches will show ways to reduce power dissipation. The aim is to achieve scientific and applied research to determine the effect of all output parameters of the MOSFET on losses. So we expect to achieve high output efficiency and accuracy in the determination of output losses. Expected results allow more precise diagnosis and method for determining the power dissipation, significantly improves the output performance. The proposed project reported mode of the output MOSFET transistors and only then proceed to assess the losses. In terms of operation modes, methods analyze static and dynamic losses in the output transistors and thus assess the effectiveness of the stage. Static losses are measured with transient resistance Rds and with a dynamic transients in switching. To assess the effectiveness is shown a modified approach for determining the parameters K and M of the company methodology published IRF [1]. Determination of initial parameters define two types of losses [2], then is defined depending on the operating voltage. Analysis continues with the removal of static and dynamic losses on MOSFET transistors. Completion of the method shows the dependence of the adjusted loss from the deduced parameters. The proposed approach will bring more clarity to determine the output power dissipation. Considering the depth field work in determining the baseline performance we think that working with European partners will lead to a complete scientific and applied decision in District Energy efficiency. The scope of the proposed project involves: 1) Development of a modified method for determining the output power dissipation; 2) A critical analysis of global methods for determining the switching losses in output MOSFET transistors 3) Comparison of field studies with the resulting models and conducting numerical experiments (numerical experiments) to determine the accuracy of the obtained models.

State-of-the-Art (about 1 ½ page)

During the recent years, the efficient output is essential for all electronic devices. The higher power dissipation in a specific inverter - the greater is the need for cooling and specific operating requirements. Low efficiency leads to higher water losses which we all strive daily to overcome. Leading here is how to reach an accurate analysis to determine the baseline efficiency of various electronic devices. To achieve high efficiency many manufacturers of power converters rely on switch operation of the output inverters. In this connection the proposed project work continues to refine and determine the losses. The attention is partly focused on one industry for the production of alternative energy associated with the use of switch output stages. In this sense, it is crucial that the output power dissipated can be determined correctly to make a proper comparison between the measured and analytical values. In the known literature [3] analytical determination of losses is based on specific parameters of the electronic switches. These parameters suggest by what signs are chosen and how the electronic switches using different software can determine the magnitude of power dissipation. In the research team of scientists led by N. Hatziargyriou published works entitled "Control And Communication For Operation Of Inverters In Future Power

Systems" Another development by author G. Brauner looks into the electronic key for Automotive Applications. Third scientific development of J. Zhu shows us a way to optimize the use inverter for photovoltaic systems.

Apart from the photovoltaic inverter, the same topologies are used in wind farms. As we know, these electronic modules are operating in power switch mode with some restrictions. According to the used output power in wind turbines, precise selection of electronic switches is required. Such selection of electronic switches applicable to wind turbines is made in the article "power electronic devices for wind turbine". Author A.Krasteva [4] recommends the use of such inverters for better transmission of electric energy at variable wind speed. According to several parameters of the electronic switch the paper shows a comparison table to select the type of electronic components. Different types of GTO, IGCT, BJT, MOSFET and IGBT are compared for several parameters: voltage, current, switched off-time, pulse bandwidth. From a description we can deduce the estimate for the most appropriate electronic element.

To reduce losses in the electronic switches are preferred electronic switches with minimal switched off-time, but in powerful elements side peak voltage appears during the switch. The resulting peak values may cause release of a voltage or current protections, so the company IRF [5] has developed special protections to address this problem. Protect against this type are applicable to all modern IGBT modules with impulse control. The article proposes the use of RCD scheme which inhibits maximum peaks obtained during the switching electronic key, and thereby protects the tem from breakthrough. Another way to manage electronic output IGBT switches is discussed in [6] The article discusses typical requirements for managing drivers for IGBT transistors. In addition this preliminary requirements development offers a new hybrid integrated circuit (HIC) which prevents a short circuit in the output bridge during commutation. A novelty in this analysis is the ruling power detection as a function of charge input circuit and the operating frequency. Complying with these parameters, the developed material provides inclusion of additional protective zener chain driving the powerful switches. The operating voltage of the zener diode is chosen according to the maximum voltage control. In all switch management inverter output stage has a significant influence on the transition losses and therefore as smaller number of electronic switches used, the lower will be the losses. This principle advocates of the development of J. Sch ¨ onberger [7]. The author proposes a new method of reducing the number of electronic switches in AC-DC-AC inverters. This reduction is achieved by combining the output diode switches with electronic groups in which the number of used power transistors is reduced by half, but the proposed method is limited to electricity generators with a maximum phase compensation to $\pi / 6$, but unfortunately this method converts input signals with variable efficiency up to 94%. All these studies suggest an extreme interest in the field of modern renewable sources. In particular, these systems use electronic inverters whose output must be measured and optimized. These developments clearly demonstrate the need to display the output losses caused by the inverter. Model description of these losses will suggest ways to reduce them. The expected high precision will reveal the outcome losses and how we can influence them. The direction of applied research results is: producers of renewable power sources, interrupted power supply manufactures and scientific research laboratories.

Reference:

[1] Jorge Cerano “Class D Audio Amplifier Performance Relationship to MOSFET Parameters” IRF 2007
[2] Long, A., High Frequency Current Mode Class-D Amplifiers With High Output Power and Efficiency. PhD Thesis from Department of Electrical and Computer Engineering University of California, CA 93106-9560. 2003, pp.90-92
[3] Jun Honda & Jonathan Adams “Class D Audio Amplifier Basics” IRF 2007
[4] Krusteva Anastassia, Marinov Tsvetan, Hinov Nikolay POWER ELECTRONIC DEVICES FOR WIND TURBINES ELECTRONICS’ 2006
[5] Rahul Chokhawala and Saed Sobhani Switching Voltage Transient Protection Schemes for High Current IGBT Modules Applications Engineering by International Rectifier 233 Kansas

St., El Segundo CA 902045, USA
[6] Eric R. Motto Hybrid Circuits Simplify IGBT Module Gate Drive Powerex Inc., Youngwood, Pennsylvania, USA
[7] J. Sch¨onberger, T. Friedli, S. D. Round, and J. W. Kolar An Ultra Sparse Matrix Converter with a Novel Active Clamp Circuit ETH Zurich, Power Electronic Systems Laboratory Physikstrasse 3, CH-8092 Z¨urich, Switzerland

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

The aim of the proposed project is to make a comparative analysis of the losses in power stage MOSFET inverters. This method uses specific parameters of the output stage, whose aim is to define the output efficiency. Out of the numerical experiments we can adequately identify the switching losses of the output stage according to the type of the output switches. Targeting of this project is a thorough practical study and grading of modified method to determinate the power dissipation in renewable power source inverters.

In this project several numerical experiments are conducted to determine the output losses in the output stage. The methods used for analysis and evaluation are based on already known computational methods by which we identify the losses in the power stage MOSFET transistors. These losses are defined by changing the load current. In order to maximize the accuracy of the results several studies have been conducted, such as:

- *Numerical experiment to identify the switching losses at various values of the load current;*
- *Numerical experiment to identify the switching losses at various values of the switching frequency;*
- *Numerical experiment to identify the switching losses during concomitant modification of the two parameters – load current and switching frequency;*
- *Comparison of the results for each of the two studies according to known methods for assessment and laboratory measurements result.*

To carry out the numerical simulation it is necessary to define the limits of the voltage supply at a constant frequency. This limitation will follow from the maximum parameters of the selected power voltage, which will determine the maximum output power. This means that exploring the modification of the output voltage will limit the power supply. We will make examination by conducting the numerical experiment with the following data: constant load resistance; variable output power; variable duty cycle. From those numerical experiments the maximum permissible value of the power supply voltage is obtained at which the maximum output power is limited to the value.

For the purposes of the scientific experiment, we will keep constant two parameters: the maximum voltage supply and the switching frequency. Then we will determine the load current modification. The purpose of the program testing is comparison of switching losses on the both known methods. In the research area there is a relatively small change of the switching losses. We also notice that the switching losses remain relatively constant. Additional parameters of the study are output capacity power supply voltage, drain current and switching time of the power transistors. In the proposed numerical simulation it is necessary to determine the limits of the frequency at the supply voltage. To conduct the scientific experiments we choose the maximum frequency to be limited to at a voltage supply. The value of this voltage is selected by the restrictive conditions for use of a transistor. The results of the numerical simulation are two additional experiments with the change of the working frequency. For conducting the research we should comply with the restrictive conditions of a few experiments. The result obtained in both studies clearly shows the same variation of switching losses regardless of the chosen method. It

is striking low divergence of results in minimum values of output current and maximum operating frequency

Scientific research proposed to develop a method for determining the effectiveness of the power stage transistors. In terms of work mode, methods analyze static and dynamic losses in the output MOSFET transistors and thus assess the effectiveness of the power stage. Static losses are estimated to active resistance "Rds". To assess the effectiveness is shown a modified approach for determining the parameters K and M of the methodology published by the company International Rectifier [1].

A point of particular interest is the simulated comparison research of the switching losses of two of the known methods [1], [2]. With reference to expression:

$$P_{total} = P_{sw} + P_{cond} + P_{gate}$$

we know that the output losses are defined as the sum of the: switching losses + conduction losses + Gate losses.

For the purposes of the scientific experiment let us change the voltage power supply. On the other hand stabilization the switching frequency. The purpose of the numerical simulation is the comparison of the switching losses Psw on the both familiar mathematical expressions. This means that the switching losses are only one component for defining the complex losses. The comprehensive scientific analysis will show that they can be compared using various methods for assessing the switching losses. In order to determine these losses there are two known methods of assessment.

These methods take into account parameters such as: power supply, drain current and conduction resistor. The first published method [3] argues that the value of the switching losses is determined by the expression:

$$P_{sw_1} = C_{oss} \cdot U^2{}_{dd} \cdot f_{sw} + I_d \cdot U_{ds} \cdot t_f \cdot f_{sw}$$

Another expression extends the analysis and defines the same losses but in the form:

$$\begin{aligned} P_{sw_2} &= [0{,}5.I_d \cdot U_{dd} \cdot (t_r + t_f) \cdot f_{sw}] + ... \\ &... + [0{,}5 \cdot C_{oss} \cdot U^2{}_{dd} \cdot f_{sw}] + ... \\ &... + [K \cdot 0{,}5 \cdot Q_{rr} \cdot U_{dd} \cdot f_{sw}] \end{aligned}$$

Considering the second expression we realize that the size of the charge Qrr depends on the fast diode connected in parallel between the source-drain (D-S) of the switching transistor. This diode is included in reverse direction to the terminals DS which protect the transistors from reverse voltage. Qrr charge is defined for the time of obstruction of the diodes tr - Figure 1, by the expression:

$$Q_{rr} = \frac{1}{t_{rr}} \cdot \int_0^{t_{rr}} i_{rr}(t) \cdot dt$$

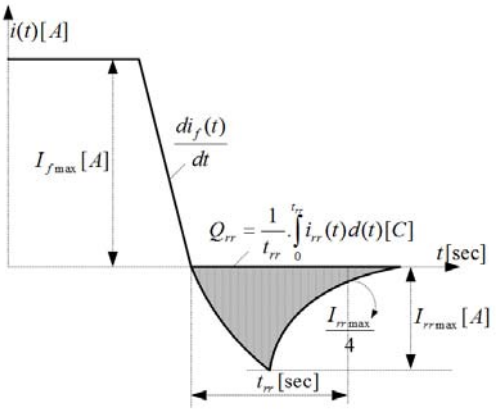

Fig.1. Diode current *i(t)* as a function of Q_{rr}

Determination of initial parameters define two types of losses, then determines the operating voltage used for power supply. Selection of appropriate switching MOSFET transistor largely depends on the magnitude of this tension.

Activities:

1.1. Critical analysis of methods for evaluating the effectiveness of the power stage. At this stage of the project a comparative analysis of contemporary methods for determining power dissipation in output switches will be carried out, as well as critical analysis of the known methods of analysis and evaluation of effectiveness. All the methods are intended to show how the output is measured and what performance can be improved in this analysis;

Development of a modified method for determining the losses in switching transistors. This consideration is limited to the typical two modes of electronic switch:

• A condition in which the output transistor is saturated and the current flow causes voltage drop on the transition resistance. Then the losses depend on the value of this resistance "R_{ds}" and are called static dissipation;

• The switching mode when the electronic key passes through deep in the blocked (or back) condition, these losses depend on the time of occlusion (or saturation) of the transistor, which includes a charge / discharge capacity of the input and switching losses are named relevant risks.

Methods for implementing the project proposal

The methodology of this project lies in the development of a modified method for measuring losses in key output transistors. Different approaches used to evaluate different parameters and therefore provide a preliminary analysis of the size of the operating voltage as a function of maximum power output of the final key step. Only when we know that a key requirement is selected transistor that can perform evicted requirements maximum output power and operating voltage. Once defined voltage selecting the appropriate MOSFET transistor with a maximum voltage

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

The uniqueness of this development is related to the development of an entirely modification method for defining the switching losses in the MOSFET power stage transistors. Presentation of final results gives an overall assessment of what can be considered in the selection and evaluation of current systems.

Expected results and benefits of the project are:

** Critical analysis and evaluation, which includes critical analysis of the known methods for determining the switching losses at the power stages;*

** Extremely high benefit for the team in technical majors after entering the results of research in the learning process.*

We consider that the study will show a significant discrepancy between the results for two switching value. At low values of this voltage the results for second result suggest low switching losses while the value of power supply. The conclusion is that within a range of the study values obtained for the switching losses differ significantly. Out of the experiments we observe a point of intersection of characteristics about power supply voltage, but they are not allowed to be criteria for the assessment

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

Methods of information and publicity of the project proposal and promotion of results among academics.

** One publication of the results in international scientific journal;*

** Maintain access to international database AES which promote research potential of the team to analyze the new developments;*

** Register to the IEEE international database with which to promote the scientific potential of all participants, taking into account the latest scientific advances to improve efficiency.*

Synergy with ongoing research (about ½ page)

The present topic addresses these issues at system level, through integrated-testing, monitoring and performance modelling.

PV Module Output Power Characterisation in Test Laboratories and in the PV Industry

The aim of the research work was to fill existing gaps of knowledge for defining specific measurement procedures for various PV technologies, to translate research results into best practice guidelines for PV industry and to provide input for standardisation working groups.

ENERGY.2012.2.1.1: Reliable, costeffective, highly performing PV systems

Penetration of PV electricity in the European market is expected to increase. In order to reach grid-parity for photovoltaics, an intensive and constant R&D support is required to achieve cost reduction of the technology (€/Wp), increased performance, functionality, reliability and lifetime. Enhancement of these aspects at cell and module level has so far been quite extensively investigated. **FR7** [http://www.2020-horizon.com/Reliable-costeffective-highly-performing-PV-systems-i388.html]

ENERGY.2012.2.5.1 Research, development and testing of solar dish systems

Further research and development is needed in order to reduce operation and maintenance costs and increase system reliability and life-time. This can be obtained, among others, by means of increased engine efficiency, increased mirror reflectivity, innovative and optimal designs and configurations, power block optimisation, and substitution of the Stirling engine with other types of engines, while keeping manufacturing costs low. **FR7** [http://www.2020-horizon.com/Research-development-and-testing-of-solar-dish-systems-i390.html]

SMA

SMA Solar inverters are characterized by a particularly high efficiency of up to 99 %, which allows for increased electricity production. The multi award-winning product range covers solar inverters for roof systems, major solar projects and off-grid systems, enabling SMA to provide a technically optimized inverter solution for all size categories and system types. Its range of services is complemented by a worldwide service network.

Fronius

We have been closely involved with solar electronics since 1992. Our aim is to revolutionise the energy supply of our planet to achieve energy self-sufficiency. The highest possible level of quality is at the forefront of all our activities. This is demonstrated not only by our powerful, grid-connected inverters, but also by our comprehensive range of system monitoring products.

SolarPlaza

The company was founded in 2004 by Edwin Koot, a senior PV expert working in photovoltaic solar energy since 1994. Solarplaza has built a network of trusted friends and personal contacts all over the world. The company has been leading and inspiring the solar industry with high level events and trade missions for more than seven years.

AVC

AVC PROVIDES BEST HEAT DISSIPATION SOLUTION IN 2010 (http://www.avc.com.tw/news_detail.asp?id=270) Asia Vital Components Co., Ltd., the biggest cooling product manufacturing company will push all-around customer application heat dissipation proposal in 2010 Electronica exhibition, show the latest heat dissipation technology and application case of the industry and provide the best heat dissipation solution of internationally renowned leading manufacturers

Dissemination – Exploitation of results (about ½ page)

- *Published scientific articles in Annual Journal of Electronics, 2011*
- Publication of research results and achievements in international forums and conferences under the auspices of the IEEE
- *Scientific technical articles in the international conference on Technical and technologies in the Burgas Free University 2012*

Time schedule (about ½ page)

Project work and time schedule per mount	0	1			2			3			4		
Proposal of the scientific research and projecting	X												
Start of the critical analyses of the project		X	X	X	X								
Development of a new method and research for participation in local and international scientific journals			X	X	X	X	X	X	X	X	X		
Preparation of materials for conferences									X	X	X	X	
Structuring the project materials and preparing the reports.											X	X	X

Description of the proposing team (as long as needed)

The proposed team clearly shows its ability to develop scientific and applied concepts in this area. In the last few years the members of the team have written numerous scientific articles and developed practical experiments with some students. Participants in the team are*:*

- *Plamen Angelov*
- *Dimitar Yudov*
- *Ivan Petkov*
- *Georgi Todorov*

Plamen Angelov

Plamen Angelov is a lecturer at Burgas Free University since 2001. Early in his career he was an assistant professor in the electronics field which takes the following disciplines: management and control of renewable energies, specialized measurements in electronics and software engineering. In the course of his scientific work his PhD at the Technical University of Sofia in 2009, while his master's degree completed at the Technical University of Varna in 2000. Between 2001 and currently is the author of 46 scientific and applied projects in the areas of electronics and specialized inverters. Nineteen of these projects are developing prototypes of various electronic devices that are successfully applied research projects for students of master's programs. For the same period has published 29 scientific papers and 36 papers in international scientific seminars. Since 2002. now a member of five scientific organizations with scientific developments in the region specialized electronic systems and control. His technical interests can be summarized in the fields: specialized electronic measurements in the power stage inverters; Design of printed electronic circuits of the power stage inverters; modern high-performance switching control amplifiers; audio and electronic measurements; Simulation analysis of electrical circuits with OrCAD , PSPICE, Altium Designer, National Instrument, Proteus. In those technical areas Pl. Angelov is the author of four textbooks.

Personal website: http://www.bfu.bg/index.php?q=node/60&id=274

Dimitar Yudov

Dimitar Yudov is Dean and full Professor in Faculty of Computer Science and Engineering of the Burgras Free University from 2001ə. He is head of five doctoral students successfully defended in the area of power electronic converters. He has participated in three international projects related to implementation and evaluation of a system of mobility of teachers and students in the European Union. Defended his thesis in the field of power converters in 1980 at the Technical University of Sofia. He obtained his habilitation in the same technical field of the Higher Attestation Commission in 1983. Owns 16 copyright certificates in power electronics. Area of scientific interests: Industrial electronics; Electronic Controllers. In these areas, Professor Yudov is the author of more than 10 textbooks.

Personal website http://bfu.bg/index.php?q=node/60&id=128

Ivan Petkov – student in BFU Burgas – f.N: 08321112

Ivan Petkov is a student in Burgas Free University, 4th year. His area of study is Communication Technologies and Computer Networks. In his High school years he was actively attending programmer competitions and seminars. His programming interests later led to the Microcontroller area. During the past years, as the renewable power sources gained more popularity, this became main aspect of scientific research and development for him. Other areas of scientific interests is LED control systems (mainly improving the efficiency and application in different areas).

Georgi Todorov – student in BFU Burgas – f.N: 08321111

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attending programmer competitions and seminars. His programming interests later led to the Microcontroller area. During the past years, as the renewable power sources gained more popularity, this became main aspect of scientific research and development for him. Other areas of scientific interests is LED control systems (mainly improving the efficiency and application in different areas).

Scientific publications:

• *Pl. Angelov Modified electronic system for control the low frequency bridge inverter - part.1., Annual journal of electronics 2011*

• *Pl.Angelov Modified electronic system for controlling the low frequency bridge inverter - part.2., Annual journal of electronics 2011*

• *Analysis of the Efficiency of Class AB Low-Frequency Amplifiers, International conference of Electronics 2010*

• *Ml. Angelova, Pl.Angelov "Practical project of the spectrum indicator in the low frequency band" Scientific conference of electronics, Sofia Bulgaria 2006*

• *P.Angelov Ml.Angelova Intelligent feedback correction of total harmonics distortion, Scientific conference of electronics, Sofia Bulgaria 2006*

• *T. Fichev, P.Wheeler, J. Clare, D.Yudov, V. Valchev, A. Van dsn Bosshe., A LCL Resonant DC-DC for Electrical Power Distribution Systems., EPE -REMC 2004 Riga, Latvia, 2007*

• *Yudov D., Mareva D.. „OUTPUT POWER REGULATION IN AUTONOMOUS INVERTER FOR INDUCTION HEATING OF WATER" BFU 2010.*

• *Mareva D., Yudov D. Marev E. „Inverter for Induction Heating of Fluids „Annual Journal of Electronics, 2010, Sozopol*