A) General Information

Acronym: DPDinv

Title of the User-Project: Determining the power dissipation in power stage inverters

TA Call:	**VTT Technical Research Centre of Finland**
Host Research Infrastructure:	**Tekniikantie 2, Espoo**
Starting Date:	**18.11.2012**
End Date:	**30.11.2012**
Lead User :	**Plamen Angelov**
Organization:	**Burgas Free University**
Additional Users:	**Yani Yanev, Georgi Kutsarov**

B) Summary of the User-Project

The proposed project focuses on the development of a modified method for determining losses in MOSFET switching power output stage. It is a well-known fact, that many modern sources (such as PV systems inverters, DC motor controllers) use output inverters to convert the signal. During its commutation, these 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 power output stage transistors. The idea stems from the high output losses in switching transistor and cause professional interest in when using the power 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. 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 Drain-Source resistance R_{ds}. Initial parameters define two types of losses [2], and later on we evaluate 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.

C) Main Achievements (Expected Results)

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. The aim 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:*

- *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.*
- *In order to accurately perform the scientific experiment, we will keep constant two parameters: maximum voltage supply (U_{ddmax}=60V) and switching frequency between f_l=50Hz to f_{hight}=10 kHz. Then we will determine the load current modification and practical result of the R_{ds} and source current. The purpose of the program testing is comparison of switching losses on the known method. In the research area there is a relatively small change of the switching losses. We also notice that the gate losses remain relatively constant with same control frequency. Additional parameters of the study are output power supply voltage, drain current and switching dissipation of the power transistors. In the proposed numerical calculation it is necessary to determine the limits of the frequency to maximum value f_{max}=10 kHz. The value of this voltage is selected by the restrictive conditions. The results of the numerical simulation are two additional experiments with the change of the four working frequency and different Load Power. For conducting the research we should comply with the restrictive conditions of a many experiments. The result obtained in both studies clearly shows the same variation of switching losses regardless of the new method.*

Scientific research proposed to develop a practical method for determining the power dissipation on the power stage transistors. In terms of work mode, methods analyze static and switching losses on the power transistors. Static losses are estimated to active resistance "Rds".

The aim 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 to f=50Hz. The purpose of the experiment is comparison of the switching losses P_{sw}. This means that the switching losses are only one component for defining the output 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 resistance R_{ds}. The first published method [3] argues that the value of the switching losses is determined by the expression:

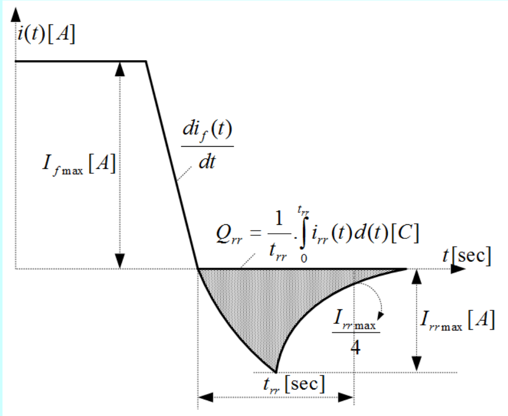
$$P_{sw_1} = C_{oss} \cdot U^2{}_{dd} \cdot f_{sw} + I_d \cdot U_{ds} \cdot t_f \cdot f_{sw}$$

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

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

Considering the second expression we realize that the value of the charge Q_{rr} depends on the fast *diode connected in parallel between the drain-source (D-S) of the switching transistor. This diode is included in reverse direction which protects the transistors from reverse voltage. Q_{rr} charge is on this diode define the switching off time on the transistor - Figure 1, by the expression:*

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



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

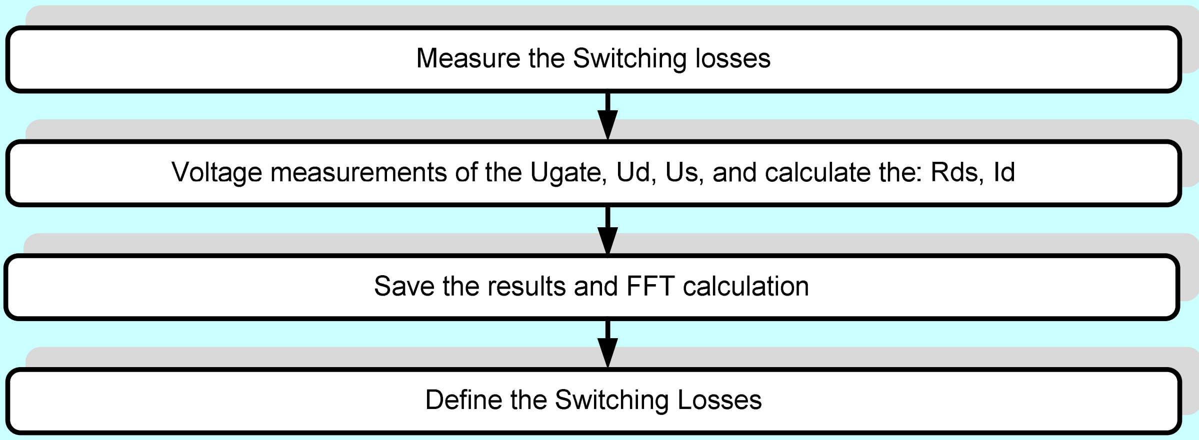
Determination of initial parameters defines two types of losses, and then it determines the operating voltage. Selection of suitable switching MOSFET transistor.

***Activities**:*

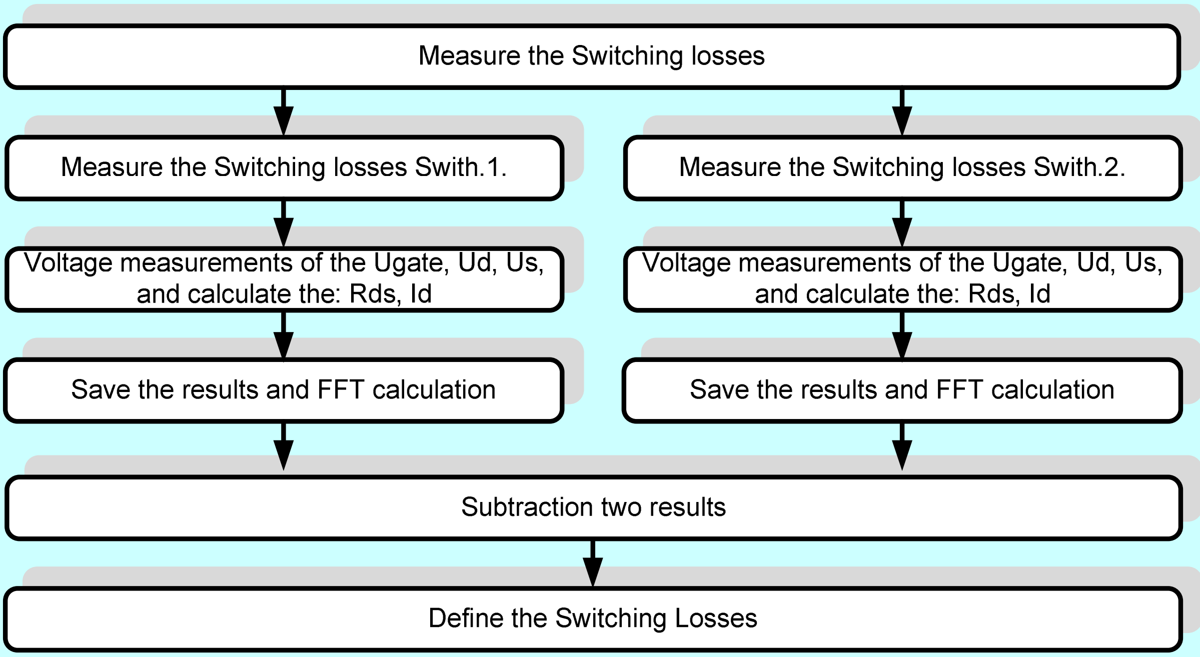
1.1. Critical analysis of methods for evaluating the effectiveness of the power stage. At this stage of the project a comparative analysis of contemporary known methods for determining power dissipation in output switches will be carried out, as well as critical analysis of the known methods of analysis 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:

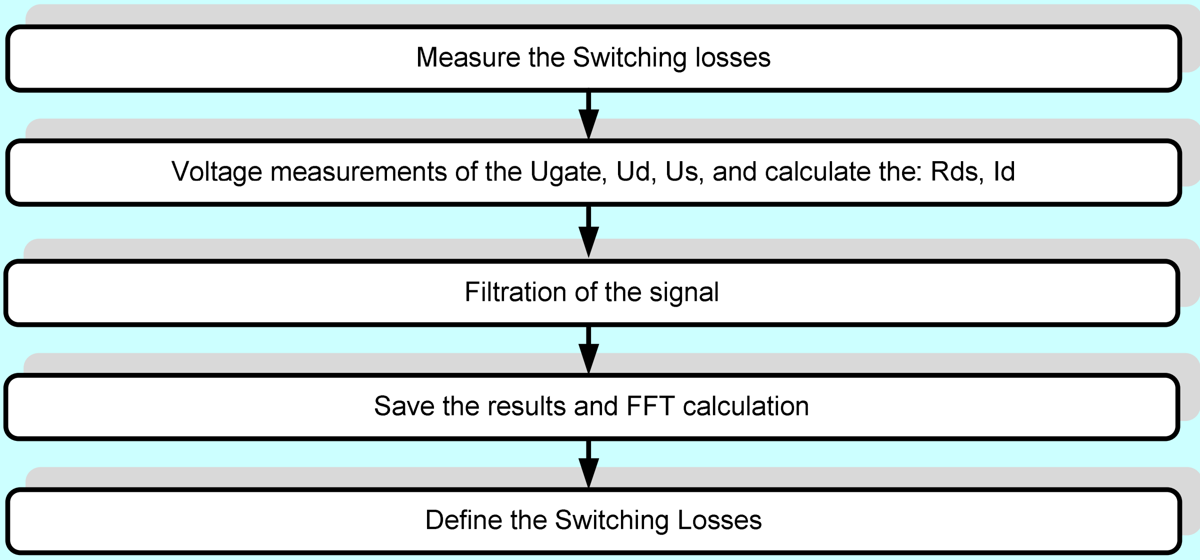
Switching losses measurement was expected to perform directly through FFT decomposition of transient process. This suggestion imposed development of the first measuring method. In general, this method structure is shown in the following figure:



Differential measurement of two transient processes is provided by another method, keeping in mind that the key moment here is measuring identical transistors. Applying different load power on each transistor is necessary, in order to keep minimum error rates. The assumption is: this limitation would cause different transient process levels (switching losses).



The third suggested method introduces the idea of transient process filtering. The provided block structure suggests use of low frequency filter, in order to separate operating signal. General structure of this method is depicted in the following figure:



The methodology of this project lies in the development of a modified method for measuring the switching losses. 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.

Expected results for the three dissipation power losses: 85-90% for P_{cond}, for switching losses - to 9-14%; and for gate losses – up to 0.1-1%. An important condition, before initializing all measurements, is to have maximum power voltage U_{dd} predefined. The expected marginal value is in compliance with transistor operating voltage.

D) Dissemination of the Results (Planned)

- Publication of research results and achievements in international forums and conferences under the auspices of the IEEE
- *Scientific technical articles on the annual journal form the Burgas Free University*

E) Use of the Resources (Expected)

Benefit of the measuring devices is to provide all necessary measurements for the project. The expected results of this measurement will be used to determine the different losses in the power stage transistor. Importance of accurate measurement of the switching parameters of the transients processing on U_{ds} and U_s voltage. We suggest supplied equipment to high precision measurement in which we obtain many accurate results.

Nr. of Users involved: 3
Access Days: 10
Stay Days: 14

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 Chokhawalaand 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., Young wood, Pennsylvania, USA

[7] J. Schönberger, 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 Zurich, Switzerland

[8] IRF830A,PD - 91878D (2003), HEXFET Power MOSFET*, International Rectifier*

[9] IRF530N, PD -91351 (2001), HEXFET Power MOSFET, *International Rectifier*

[10] IRFI540N, PD - 9. 1361A (2001), HEXFET Power MOSFET*, International Rectifier*

[11] IRFP250N, PD – 94008A (2004), HEXFET Power MOSFET*, International Rectifier*