



Tutorial: Reliability in power electronic systems

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SCOPE AND BENEFITS

Advances in power electronics enable efficient and flexible processing of electric power in the application of renewable energy sources, electric vehicles, adjustable-speed drives, etc. More and more efforts are devoted to having better power electronic systems in terms of reliability to ensure high availability, long lifetime, sufficient robustness and low maintenance cost. However, the reliability predictions are still dominantly according to outdated models and terms, such as MIL-HDBK-217H handbook models, mean-time-to-failure (MTTF), and mean-time-between-failures (MTBF).

CONTENTS

Today customer expects up to 20 years of lifetime and they also want to have a “failure free period” and all with focus at the financials. The tutorial will show part of a practical approach to understand the way for Design for Reliability in power electronics. This approach is also the common interest for the companies involved in the CORPE research center at Aalborg University (<http://www.corpe.et.aau.dk/>). CORPE is a strategic research center between the industry and universities. It is led by Aalborg University and the following Companies: Grundfos, Vestas, KK-Electronics and Danfoss Power Electronics. The overall goal is to produce cheaper more reliable electronic devices, which will accelerate the transition to sustainable energy sources.

The tutorial will be organised in 4 main parts:

1. Introduction to modern reliability

The need Cost of poor Quality and Reliability is an important parameter when optimizing new designs or improve products. What are the industries expectations to the design engineers in the future?

Why you cannot use FIT and MTBF to reach such goals. Some methods have been obsolete and a lot of new skills are important. Some of these methods and needed attitudes will be presented.

For reaching the intension of the managers we have to use their language. How you can calculate Cost of poor Reliability. It is very important to be sure that the reliability models and quantitative figures developed are related to the real world.

2. Reliability Challenges in Power Electronics

A collection of methodologies based on physics-of-failure (PoF) approach and mission profile analysis are presented to perform reliability-oriented design of power electronic systems. The corresponding design procedures and reliability prediction models are provided. Further on, a case study on 10 MW wind power converters is discussed with emphasis on the reliability critical components IGBTs and DC-link capacitors. Different



aspects of improving the reliability of the power converters are mapped. Finally, the challenges and opportunities to achieve more reliable power electronic systems are addressed.

3. Failure mechanisms and testing of semiconductor power devices operated at the edge of SOA

The basic physical mechanisms involved in the failure of semiconductor power devices when operated under highly stressing electrical conditions (short circuit, overload, overvoltage, etc.) will be presented. The attention is focused on unstable phenomena which may cause a strongly localized power dissipation in the device structure and the consequent device failure. The test of the devices under these conditions can be conveniently performed in a non-destructive way. For this purpose the Device Under Test (DUT) is operated in presence of a protection circuit which is able to quickly zero the energy dissipated by the DUT at the occurrence of a potentially destructive unstable condition and, in many cases, to prevent its failure. The tutorial describes the main characteristics and the design principles of such non-destructive testers. The basic instabilities occurring during the highly stressing operations of the power devices are presented and a particular attention is devoted to the precursors, which precedes these instabilities and help in performing the protection action.

4. Real time monitoring and prediction in components and systems

The main focus is on identifying methods for the real time (on-line) detection of the lifetime (wear-out) state of the power transistor (or power diode) by monitoring various relevant (thermal, electrical, optical etc.) sensor signals.

The goal is to make possible the desired real time detection during normal operation of a power converter. The developed methods will most likely include sensors for measuring physical quantities (such as voltages, currents and temperatures), communication and software based models and signal processing. Some of the features could be integrated into the gate driver circuit for power devices in order to get access to the ‘hot’ (high voltage) side of the power converter in an economical way.

Active power control methods based on real time monitoring will be also discussed.

Schedule is as follows (to be adapted to suit the length of your tutorial):

Monday, September 2nd - Tutorial day (Location: University of Lille)

08:00 - 09:15	Registration for Tutorials
09:15 - 09:30	Introduction to CORPE, speaker Frede Blaabjerg
09:30 - 11:00	Introduction to modern reliability, MCF curve, cost of poor reliability, robustness, speaker: Peter de Place Rimmen
11:00 - 11:30	Coffee break
11.30 - 13:00	Reliability Challenges in Power Electronics, Design for Reliability of Power Electronic Systems, speaker Frede Blaabjerg
13:00 - 14:00	Lunch break
14:00 - 15:30	Failure mechanisms and testing of semiconductor power devices operated at the edge of SOA, speaker: Giovanni Busatto
15:30 - 16:00	Coffee break



16:00 - 17:30 Real time monitoring and prediction in components and systems, active thermal control and case studies

17:00 - 19:00 Possibility for registration for the EPE2013 ECCE Europe in the lobby of Lille Grand Palais

WHO SHOULD ATTEND

Researchers and engineers who seek for the basic knowledge for entering in this field, ranging from component level to system level, from physics of failure to statistical analysis. Prerequisite is basic power electronics and statistical concepts.

Technical Level: Technical level of the tutorial (beginners, advanced, etc..)

Beginners

ABOUT THE INSTRUCTORS

Peter de Place Rimmen

Peter de Place Rimmen is today Reliability Advisor at Danfoss Power Electronics A/S in Denmark since 2009. Peter has worked with practical approach implementing Reliability during the last 25 years in followed companies: Vestas Wind System R&D from 2004 to 2009, Grundfos Management from 1997 to 2004 and Bang & Olufsen R&D from 1988 to 1997. Before that he had careers at B&O as constructor, Test engineer, Plant manager and Project manager. Peter had for some time participated in IEC dependability group. Peter has together with Nokia trained Nokia R&D and Vestas R&D people around the world in “Design for Quality and Reliability”. Today Peter is participating in CORPE Centre of Reliable Power Electronics at Aalborg University, participating in ZVEI “facts sheets group” for robust validation, board member FAST (Danish Society for Applied Statistics) and initiated in 2001 and member of the Danish Six Sigma ERFA-group, subgroup of FAST.

Peter holds 1½ patent for Vestas concern Lifetime improvement by thermal control improvements, and for Danfoss he hold 2 patents concern Dehumidifier for enclosures and he has filled and applied 1 patent for Monitoring device usage for stress in the field.

Frede Blaabjerg, IEEE Fellow

He was employed at ABB-Scandia, Randers, from 1987-1988. During 1988-1992 he was PhD. student at Aalborg University, Denmark, became Assistant Professor in 1992, Associate Professor in 1996 and Full professor in power electronics and drives in 1998. He has been part-time research leader at Research Center Risoe in wind turbines. In 2006-2010 he was dean of the faculty of Engineering, Science and Medicine and became visiting professor at Zhejiang University, China in 2009. His research areas are in power electronics and its applications like in wind turbines, PV systems and adjustable speed drives. He has been Editor in Chief of the IEEE Transactions on Power Electronics 2006-2012. He was Distinguished lecturer for the IEEE Power Electronics Society 2005-2007 and for IEEE Industry Applications Society from 2010-2011. He has been Chairman of EPE'2007 and PEDG'2012 – both held in Aalborg

He received the 1995 Angelos Award for his contribution in modulation technique and the Annual Teacher prize at Aalborg University. In 1998 he received the Outstanding



Young Power Electronics Engineer Award from the IEEE Power Electronics Society. He has received thirteen IEEE Prize paper awards and another prize paper award at PELINCEC Poland 2005. He received the IEEE PELS Distinguished Service Award in 2009 and the EPE-PEMC 2010 Council award. Finally he has received a number of major research awards in Denmark. Finally, he is also an ERC Advanced Grant holder

Giovanni Busatto

He was employed at MILMAN, Naples, Italy, from 1981-1984. During 1984-1992 was Researcher at IRECE (an Institute of the Italian National Council of Research) in Naples. In 1992 became Associate Professor at the University of Naples "Federico II", Naples, Italy, and full professor in power electronics at the University of Cassino and Southern Lazio, Cassino, Italy, in 2001, where he is the President of the PhD School of Engineering. In 1986 and 1987 he was visiting researcher at "T.J.Watson" IBM Research Centre - Yorktown Heights - NY - USA. and in 1992 at NIST (National Institute of Standard and Technology) - Gaithersburg - MD - USA.

He has been the national coordinator of research programs on Power Electronics founded by Italian Space Agency (ASI) and Italian Ministry of Education, University and Research (MIUR). He has been and is the scientific responsible of research contracts with leading companies in the field of Power Electronics (ST-Microelectronics, ANSALDOBREDA, SIEMENS, FAIRCHILD). He has been the General Chairman of the 4th International Conference on Integrated Power Electronics Systems, CIPS 2006, and the 21st European Symposium on Reliability of Electron Devices, Failure Physics and Analysis, ESREF2010. The research interests include modelling, simulation and non-destructive characterization of power devices with a particular attention to the instabilities that are observed when they are operated in highly stressing conditions and during cosmic ray impacts. His scientific production is summarized in more than 120 papers on international journals and conferences proceedings.

Marco Liserre, IEEE fellow

He was assistant and then associate professor at Bari Polytechnic from 2004. He is Professor in reliable power electronics at Aalborg University (Denmark). He has published 162 technical papers (40 of them in international peer-reviewed journals, of which 19 in the last five years 2007-2011), 3 chapters of a book and a book (Grid Converters for Photovoltaic and Wind Power Systems, ISBN-10: 0-470-05751-3 – IEEE-Wiley, also translated in Chinese). These works have received around 6000 citations. He has been visiting Professor at Alcala de Henares University (Spain) and at Christian-Albrechts University of Kiel, Germany, as Mercator professor.

He is member of IAS, PELS, PES and IES. He is Associate Editor of the IEEE Transactions on Industrial Electronics, IEEE Industrial Electronics Magazine, IEEE Transactions on Industrial Informatics, IEEE Transactions on power electronics and IEEE Transactions on sustainable energy. He has been Founder and Editor-in-Chief of the IEEE Industrial Electronics Magazine, Founder and the Chairman of the Technical Committee on Renewable Energy Systems, Co-Chairman of the International Symposium on Industrial Electronics (ISIE 2010), IES Vice-President responsible of the publications. He has received the IES 2009 Early Career Award, the IES 2011 Anthony J. Hornfeck Service Award and the 2011 Industrial Electronics Magazine best paper award. He is



senior member of IES AdCom. He has been elevated to the IEEE fellow grade with the following citation “for contributions to grid connection of renewable energy systems and industrial drives” .



Frede Blaabjerg



Giovanni Busatto



Marco Liserre



Peter de Place Rimmen



B. The organization of the tutorial day

Your tutorial will be organized if and only if enough participants did actually register to your tutorial. This is why it is so important that you take great care in the announcement material. The secretariat will keep you informed of the evolution of the number of participants for your tutorial, and give you the “green light” as soon as possible. Please note that participants tend to register later and later, which makes the task of the organizers quite difficult.

The material that will be handed out

When setting up your hand-outs, do not forget that your audience speaks many different languages. Your text will be included in a tutorial book: please provide your participants with reference material. Additionally to your text, your slides will be provided to the participants on paper. We will print 3 slides per page to allow participants to take notes, like in the attached example. Please remember that your slides will be printed in Black and White, so make sure that the colours of your slides will still be readable in Black and White.

Your slides should follow the rules of good practice as for lecture presentation regarding, f.e. the size of characters, quantity of information contained in one slide and number of slides. An example of slides is provided in attachment as well.

Once it is decided to organize your tutorial, the secretariat will provide you with the practical information for the organization on site. Please make sure to send your material before the deadlines, to ensure smooth organization. The material will be duplicated on site and the e-mail address where to send your material will be communicated with the final acceptance mail. Should you have special needs regarding the organization of the day itself, please make sure to make your requests on time.