Partial discharges measurements at the constituents’ level of aerospace power electronics converters

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**Abstract**

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Partial discharge detection in electric apparatus fed by PWM like inverter in aircraft environment: a laboratory study

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Partial discharges measurements at the constituents’ level of aerospace power electronics converters Benjamin Cella (1), Thierry Lebey (2) 1 : Liebherr Elektronik GmbH, Peter-Dornier-Straße 11 88131 Lindau, benjamin.cella@liebherr.com 2 : Laplace laboratory, 118 route de Narbonne 31062 Toulouse, thierry.lebey@laplace.univ-tlse.fr Abstract Increasing the voltage in aircraft applications may induce reliability problems associated to the occurrence of partial discharges (PD) in systems which are not supposed (and have not been designed) to endure them. Moreover, the specificity of the environmental conditions (temperature, pressure, relative humidity, …) and of the harsh electrical conditions (high voltage, high frequency, high dV/dt, …) contribute to the risk of Partial Discharges. This paper describes the assessment of a new method to detect PD in aerospace Power Electronics (PE) systems. In order to properly understand the behavior of PD in these systems, the method is first applied on the constituents i.e on the different types of insulating materials used to build the components (PCB, Inductance, Capacitance, Busbars, Power Modules, …) used in aerospace PE inverters. This investigation is the first step of a larger study aiming to evaluate the validity of this method to detect PD in a complete aerospace PE system during operation. Introduction Moving towards more electrical airplanes consist of replacing heavier systems (mechanical and pneumatic) to reduce the weight of the aircraft while assuming a simpler maintenance. To answer to this increasing power demand, increasing the voltage has appeared as the best solution. However, such a voltage increase leads to the risk of PD occurrence [1][2]. Lot of works has already been devoted to PD in such an environment. They have been mainly developed on cables or harnesses [3] or on machines but under electrical stresses (AC or off line) which are far from being representative of the real power conversion chain conditions. This later is constituted of an inverter, a cable whose length must be variable and of an electrical machine. Electrical stresses are therefore very
different as regards the types of equipments (and of its constitutive components) under consideration. Hence, DC, AC PWM (high dV/dt, high frequency voltage waveforms) have to be taken into account when dealing with the power conversion chain. The aim of the study presented here is the very first step in the route to guaranty the design of PD free inverters by taking into account the specificity of the different stresses applied on the electric components (and of course on their insulating constituents) and of the process for realizing them. This paper describes the tests realized on samples made with insulating constituents coming from aerospace power electronics converters. Partial discharges measurements are performed using a new detection method based on a nonintrusive sensor while comparing its results (when it is possible) to the ones obtained thanks to a classical method. Materials used as isolation in these systems are first listed and then tested in different conditions. Partial discharges definition Detecting PD in a harsh environment such as the one associated to PWM application is still appearing as a difficult task [4]. Most of the PD systems are tracking pulse-like voltages whereas it is the most likelihood that the glow or pseudo glow discharges have to be detected. [5][6][7]. Definitions have to be clarified and classifications have to be made now to differentiate at the same time, the different types and the different natures of discharges depending on the voltage and environment specificities since as mentioned before their nature allow a specific detection tool [8]. The different types of discharges are mainly associated to the different geometries of the defects where they occur, whereas the different nature is associated not only to the environmental conditions but also to the nature of the electrical stresses. The former correspond to the so called Corona or Internal/Void or External/Surface discharges whereas the later may be of Pulseless or Silent or Glow or Streamer or Townsend type respectively. To properly study the insulating constituents’ samples, the whole range of type and nature of discharges has to be studied. This implies knowing how to create different types of defects while producing the different discharges. Figure 1 summarizes the different types of defects while Figure 2 presents the different nature of discharges. Fig. 1: Different types of defects: A: internal, B : Surface, C: Corona, D: Treeing Fig. 2: The different nature of discharges Different types of samples must be realized to correspond to both the different type of defects (and of constituents) whereas the different nature of discharges will be obtained on these different samples by changing the voltage waveforms (AC/DC/Pulse like) and environmental conditions (Pressure). Surface discharges (external discharges) will be studied thanks to different types of twisted pairs of enameled wires (figure 3) while representing the insulating materials used for inductances or transformers. Fig. 3: Example of standardized sample [9] to study external defects Internal discharges will be studied thanks to vented samples (figure 4) while aiming to represent insulating materials used in capacitors, busbars and PCB. Fig. 4: Example of vented sample to study internal defects Finally, Corona is studied thanks to the classical needle to plane configuration. Partial discharges detection methods Two detection methods are used and compared (as long as it is possible). The classical method represented in figure 5 is intrusive, and rests on the utilization of a coupling capacitor and of a filtering. It is mainly used in AC but is unable to be used under PWM or DC conditions. A new method using non- intrusive sensor associated to high frequency filtering has been developed recently. It uses a stripped coaxial cable and the experimental set up is presented in figure 6. Fig. 5: Classical PD detection method using a coupling capacitor Fig. 6: Experimental set up for PD detection under harsh environment The contact between the stripped coaxial cable and the power source wire creates a capacity through which the high frequency current of the partial discharges will flow. The signal measured is then filtered to suppress low frequency components, due to inverter switching, and eventual high frequency external noises. An example of PWM on line detection in a power conversion chain is given in figure 7. Fig. 7: PD detection (pulse of few mV on the green signal) in a PWM environment. In this work, the two experimental set-ups are used on the different types of samples and for the different natures of discharges. Moreover, for the new method, different filters are used to estimate the best frequency range for partial discharges detection. An example of result is given in figure 8 where the signal is measured during AC tests on an external type defect sample. It appears clearly that the 70MHz filter (red curve), because of its higher PD magnitude, its number of impulse and its early occurrence, is the most suitable to detect partial discharges. Fig. 8: PD measurements on external type defect samples under AC voltage. Reference curve (yellow), Band pass (BP) 11MHz (green), BP 30MHz (blue), BP 70MHz (red). All the samples were measured for the three voltage types (AC, DC, and Pulse) and relevant characteristics as Discharge Inception Voltage, Partial Discharges magnitude, time lag (when possible), and number of discharge were recorded. These data allow getting a better understanding on the most suitable detection method (including filtering range) and on the robustness of our approach. All these results will be detailed and discussed in the final paper. Conclusions PD existence in the power conversion chain used in aerospace applications could be detrimental to their reliability and could induce key issue regarding safety. Different approaches are developed today to avoid their appearance. In this work, we focus on the insulating materials used in the different components present in a power converter. Our aim is to reproduce the different type of defects and nature of discharges able to be encountered in such a harsh environment in order to identify their signature and to detect them in real systems. Such an approach will allow on one hand to confirm the quality of our new partial discharges detecting method and on the other hand, to develop in the future PD free power converters. 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