Title: Reliability of Power Electronic Converters for Offshore Wind and Subsea Oil Applications

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Abstract

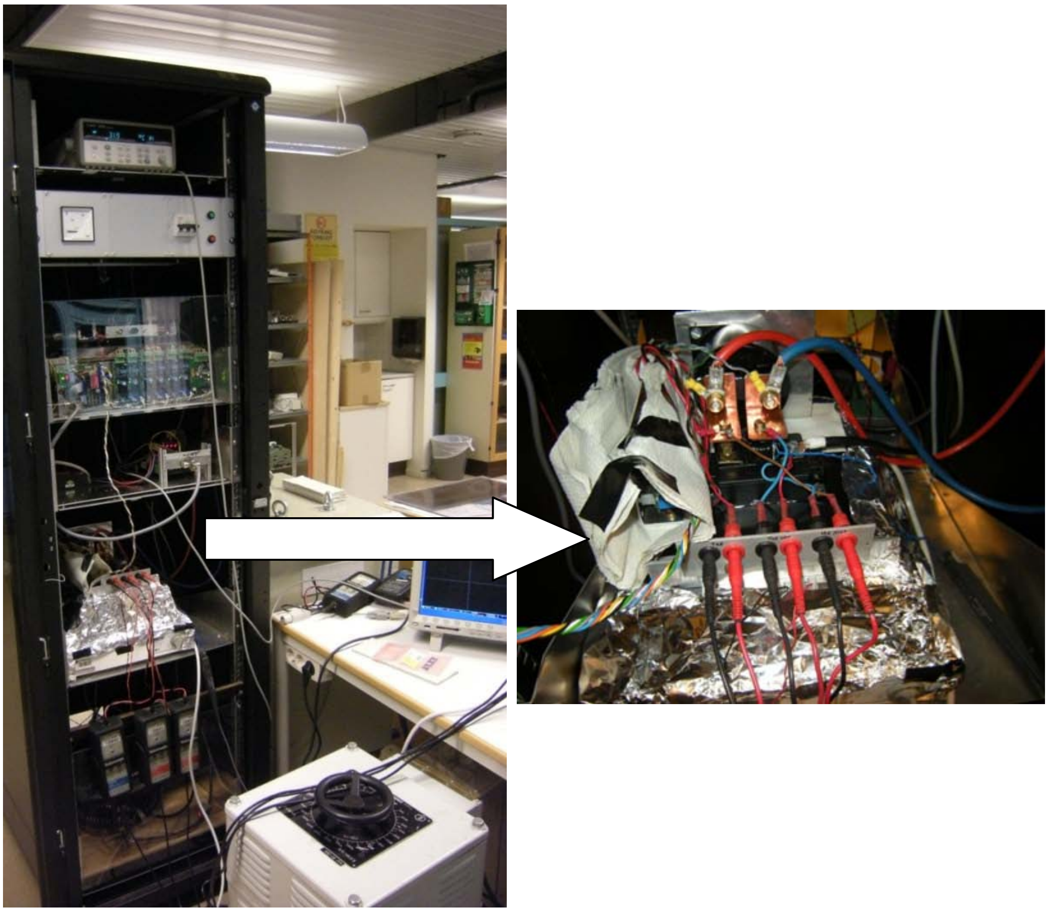
The increased demand of offshore power conversion systems is driven by newly initiated offshore projects for wind parks and oil production. Because of long distances to shore and inaccessibility of the equipment long repair times must be expected. At the same time the offshore environment is extremely harsh. Thus, high reliability is required for the converters and it is important to have good knowledge of the switching devices. This project explored state-of-the-art and developing trend of IGBT module technology, summed up the common failure mechanisms of IGBT module, and investigated switching characteristics and losses of commercially available IGBT modules to be used for this application. It focuses on losses depending on current levels, operation temperatures, and show differences between several devices of the same type. Some tests show how device characteristics and losses change when the device has been exposed to stress over some time.

This project was based on both theoretical study and experimental work. Collecting new development and evolution information of IGBT, and summing up the failure mechanics will pave the way for the further research. The literature study compared some IGBT concepts such as Trench- *vs* Planar- IGBT, and NPT-, PT-, *vs* FS-/SPT- IGBT, as well as the press-pack IGBT and SiC- IGBT. The common failure mechanisms like package-related failure, cosmic ray and irradiation caused failure and failure during application also investigated.

The experimental work investigated the dynamic performance and long-term stability. Employing the double-pulse-testing, the experiment acquired the switching time and energy dissipation at different temperatures, different power levels as well as different gate resistances. The repetitive switching test and power cycling test also expose IGBT modules to stress over some time, and then compare the double-pulse-testing results with before which used to predict the long-term stability. Base on the power cycling test, the relation of conducting voltage and temperature also explored. In addition, several identical IGBT modules also tested at some conditions to verifying the accuracy and credibility of the used methodology.

Results

Turn-on and turn-off times and energies are function of IGBT operation condition. On other words, device voltage, current and junction temperature. For the same V_{CE} and junction temperature, the higher the collector current the longer the turn-on time while the shorter the turn-off time. However, turn-off energy loss increases. Higher energy loss can be explained by the higher charge recovery of the FWD and the longer tail current. Generally, energy loss increases as the temperature increases. During the turn-on, delay time is almost constant at different temperatures, while I_C rise time increases. This leads to higher loss during the turn-on. For example, turn-on energy was increased by 25.4%, when the temperature rises from 25 ^{o}C to 125 ^{o}C for same V_{CE} and $I_{C.}$ During turn-off, energy losses increase with temperature. A 39.5% increase in E_{off} was recorded when the temperature rises from 25 ^{o}C to 125 ^{o}C. The reverse recovery energy dissipation increased almost 2 times when temperature increase form 25 ^{o}C to 125 ^{o}C. The FWD energy losses increased 34.2% when turn off the IGBT. By employing the repetitive switch testing and double pulse testing, the experiment also shows that the IGBT can still has great performance even been exposing to stressful conditions over some time. In addition, the conducting voltage increases with the temperature.



Picture of Double Pulse Testing Setup