SiC Power Modules Test using Inverter Closed-Loop Control and Electric Motor Emulator

- Active Power Cycling Test of Automotive SiC Power Modules based Inverter in Emulated Load Conditions -

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This paper introduces a complete system to perform aging tests for traction inverters power modules in emulated conditions, similar to the final automotive application. The system has the capability of controlling the power modules as if they were mounted on a real inverter, thermally conditioning the cooling fluid and emulating a real load with an Electric Motor Emulator (EME).

Modern automotive inverters are realized using power modules based on SiC MOSFET technology, which have a higher power density compared to Si semiconductors, therefore their thermal reliability becomes essential and consequently, it is necessary to perform aging power cycles. In a SiC MOSFET the most fragile connection consists in the bond wires; indeed, during the normal working conditions the bond wires are dilated and contracted by the temperature variation of the die and therefore, this can lead to potential failures. The aging of the SiC MOSFETs is basically a result of thermal stress. The failures can be detected from the thermal resistance degradation and the increase of the on-state resistance, two factors that are estimated at the end of the performing of the power cycles. The proposed system performs power cycles, using the same DC voltage, control algorithms and load conditions of the final automotive application. The system performs the thermal conditioning of the cooling fluid, controls the power modules to emulate the behavior of a real inverter, acquires the drain-source (Vds) and gate-souorce (Vgs) voltages during the power cycles execution, and emulates an active load with the possibility to change the power factor. The gates driving signals for the SiC MOSFETs are generated by the vector current control and the Space Vector Pulse Width Modulation, which run on an FPGA as part of a real-time target machine. Different power cycles can be configured with the setting of the following parameters: duration of the power cycle, number of cycles, thermal profile of the coolant, maximum phase current peak and electrical frequency to be reached. The management of the power cycles is done by the same FPGA system which emulates the real inverter, this allows to control all the before mentioned parameters and furthermore, to trigger the signals for the acquisition of the Vgs and Vds MOSFETs' voltage waveforms during the cycles. The inverter's load is based on an EME which emulates different types and sizes of electric machines or electronic loads, acting like an active load, with the possibility to recirculate the energy trough a dual Battery Simulator (one output channel is connected to the emulated inverter under test and one channel is connecter to the Electric Motor Emulator).

The advantage of this solution is that the power modules under test will act exactly as if they were controlled by a real inverter and connected to a real load. In case of electric machine emulation, the validation activities can be implemented without having to resort to dynamometer benches; this means that there is no use of rotating parts and thus, there is no need of constant maintenance.

This paper presents the test results and the acquisitions obtained by the emulation of the active load and of the inverter, with the generation of the PWM control signals to the power modules.

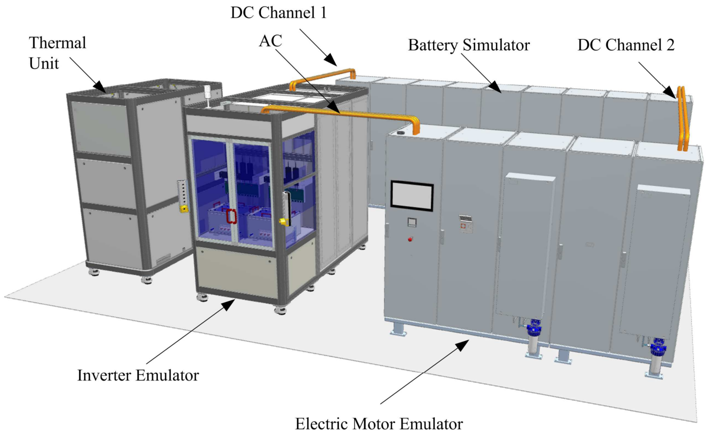

Fig.1 System Layout