AI-based V_{CE} prediction of semiconductors

In order to predict when a power semiconductor will fail, its collector-emitter voltage V_{CE} has to be monitored. In this work, we create a proof of concept for predicting the collector-emitter voltage with artificial intelligence (AI) from variables such as root-mean-square (RMS) current, semiconductor junction temperature and frequency.

Experimental inverter setup to gather real-world data

Why AI?

Inverters are used extensively in the areas of power conversion and motor drives. Being able to predict the failure of an inverter would save valuable breakdown time of cars, wind turbines, and industrial machinery. Most existing inverters do not offer the possibility to monitor the collector-emitter voltage V_{CE} of the semiconductors. Methods that have been developed to predict V_{CE} without AI are based on physical models, often computationally intensive and not mature for real-world applications.

AI gives the opportunity to monitor V_{CE} without understanding the entire thermal and electrical system of the application or the semiconductor.

Procedure

A prototype IGBT inverter with a simulated load was provided for the project. Then, data was gathered. The data had to be adjusted to simulate a real-world inverter. Using both physical and statistical methods, outlying and nonsensical measurements were detected and removed. Then, AI was trained with the data.

Results

For low frequencies, the AI can predict V_{CE} relatively accurately within $\pm 12\,\text{mV}$. For higher frequencies, the AI prediction accuracy reduces to $\pm 30\,\text{mV}$. This accuracy is not high enough to justify using AI. Instead, the author recommends building new inverters with integrated V_{CE} measurement circuitry. The author implemented a low-cost V_{CE} measurement printed circuit board (PCB) to prove the effectiveness of such a solution.

Why are V_{CE} measurements important?

Power semiconductor junctions degrade over time. The time for a semiconductor junction to fail is determined by the amount of thermal cycles (cold-hot occurrences within a semiconductor) and their respective temperature differences. Furthermore, an IGBT's nominal V_{CE} tends to rise over its lifetime. We can use V_{CE} to predict both: Firstly, junction temperature is almost only dependent on V_{CE}, input current and switching frequency. Secondly, changes in V_{CE} can hint to semiconductor aging and help predict its remaining lifespan.

Project Team:
Jaspera Rohner

Client:
MTAL GmbH, Gänsbrunnen SO

Coaches:
Prof. Dr. Renato Minamisawa