Magnetic Sensing for Leak Current Detection in Electric Vehicles

Students

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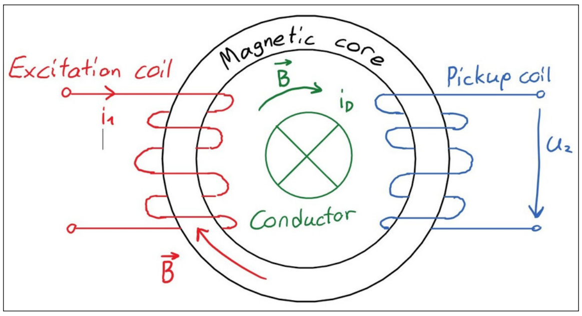
Objective: The company Maglab AG designs and supplies current sensors to leading EV industries. The increasing demands for extended range on these vehicles lead to higher voltage powertrains. To ensure the users' safety, new regulations are put on the power links. So called ground fault detectors and interrupters (GFDIs) must detect leakages and interrupt the circuitry upon fault. Different from safe operation, if a leakage occurs, the power supply lines of the battery will no longer supply the same current. The leak current could pose a serious risk of injury to passengers or damage other electronics.

As the current coming from a battery is DC, the effect of induction cannot be used to determine the amplitude. One possible solution is the use of Hall-Sensors. State of the art Hall-Sensors can detect DC and AC down to 6 mA, but they are expensive and very sensitive to changing temperatures. Hence a different, possibly more accurate, detection method was investigated in this work.

Approach: A magnetic core with coils was developed by Maglab with the purpose to measure a differential DC and AC. This sensor is based on the fluxgate principle. These sensor types are known for the high level of sensitivity, wide dynamic range, and a low temperature sensitivity.
The overall goal is to detect 3 mA of DC leakage. At first it was tried to model the system from firsts principles to determine a transfer function. However, the attempts to saturate the core were unsuccessful and the system showed many non-linearities. Developing a lowpass filter was considered to reduce influence of harmonics present in the system. After an in-depth investigation, it was concluded that the magnetic core must be flawed. The approach of modelling the system dynamics was stopped and a data-diven approach was chosen to identify the system.

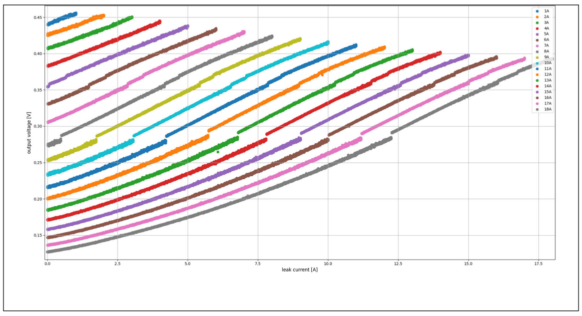
Result: During the tests, a drop in output voltages has been observed for inputs of increasing DC amplitudes. Treating the setup as a black box, the measuring process was automated to acquire large data sets of input-output behaviour. As the progression of the output voltage varies for different base currents, data was gathered for an entire range of operating DCs.
In order to measure the output voltage with the highest accuracy, the oscilloscope measured in different resolutions, introducing some glitches in the stored data.
Control over the laboratory equipment was automated with pyVISA, allowing for data processing and further data utilization in Python. To get more data and reduce the influence of noise, each sample was acquired ten times.
Curves were fitted to data using polynomial regression, enabling the setup to detect and assess leak current based on the measured voltage amplitude on the secondary side. These polynomial curves are found using cross-validation on the previously acquired data by minimizing the Mean Squared Error.

Basic arrangement of a fluxgate sensor as used in this work
Own presentment



Induced voltages on secondary side of the fluxgate with a sinusoidal input, showing the non-linearity of the system
Own presentment

Progressions of the output signals for a range of DC over increasing leak current
Own presentment



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Subject Area
Embedded Systems, Sensorics, Electromagnetic fields and waves

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