ArchitectECA2030

SC 1 Demo 1.1 Key Card

Foreign object detection system within a wireless charging system

Main aim	
A foreign object detection (FOD) system is a safety-relevant subsystem of a wireless charging system with inductive power transfer. As a basis for virtual development and validation, the magnetic field of the charging system's ground assembly (GA), the thermal behaviour of standardised test objects and the properties of passive inductive sensors for the detection of metallic foreign objects are characterised and simulated.	
Partner	*TU Dresden / ILK (TUDR)*
ECS value chain	*Research / Tier 1 / Tier 2*

State-of-the-art	**Beyond SotA / Innovation**	**Targeted TRL**
• *Standardized safety objectives for FOD systems* • *Standardized fundamental test procedures for the appropriateness of the FOD system*	• *Characterization of test objects and potential risks* • *Simulation of FOD including parts of the charging system* • *Verification by practical measurements*	*TRL3 - TRL4*

Link to project objectives

Objective	***Addressed (Y/N)***	***How***
O1 – Continuous robust design optimization for each part in the ECS value chain	*Y*	*The characterisation of the sensors in interaction with a real wireless charging system takes into account many of the practically relevant influences and, together with the modelling and simulation of the FOD system, allows to draw conclusions about the interrelationships of the working mechanisms and thus the development of better adapted sensors. (KT1, KT2)*
O2 – Framework for safety validation of ECS value chain	*N*	
O3 – Identification & management of residual risks over the entire ECS value chain	*Y*	*The characterisation of standardised test objects in the magnetic field and the performance evaluation of the selected sensors in detecting these objects allow to draw conclusions on the efficiency of the FOD system and thus on the residual risk. (KT1, KT2)*
O4 – End-user acceptance by trustworthy ECS value chain	*Y*	*Optimized sensors and automatic functionality tests during the entire operating life of the FOD system increase the reliability of the charging system and thereby contribute to higher end-user acceptance.*
O5 – Zero emissions, zero crashes, zero congestions by ECA2030-car	*N*	

Joint demonstrator (JDEM)	**Linked supply chains (Y/N)**		**Considered MonDev layers**	
Demo 1.1				
	SC1	*Y*	***System (S)***	*N*
	SC2	*N*	***Subsystem (SS)***	*N*
	SC3	*N*	***Component (C)***	*N*
SC	***SC4***	*Y*	***Subcomponent (SC)***	*Y*

Setup

The demonstrator shows the detection of metallic foreign objects on the test bed in a real charging system using the example of passive inductive sensors (Figure 1). In such a scenario, both the effects caused by foreign objects and the properties of the sensor coils depend on the characteristics of the magnetic field of the GA. Other factors include the size and shape of the components, the material they are made of, and their positioning relative to each other. Therefore, the aspects of foreign object detection are investigated on different test objects and sensor coils. The demonstrator is developed by ***TUDR****.*

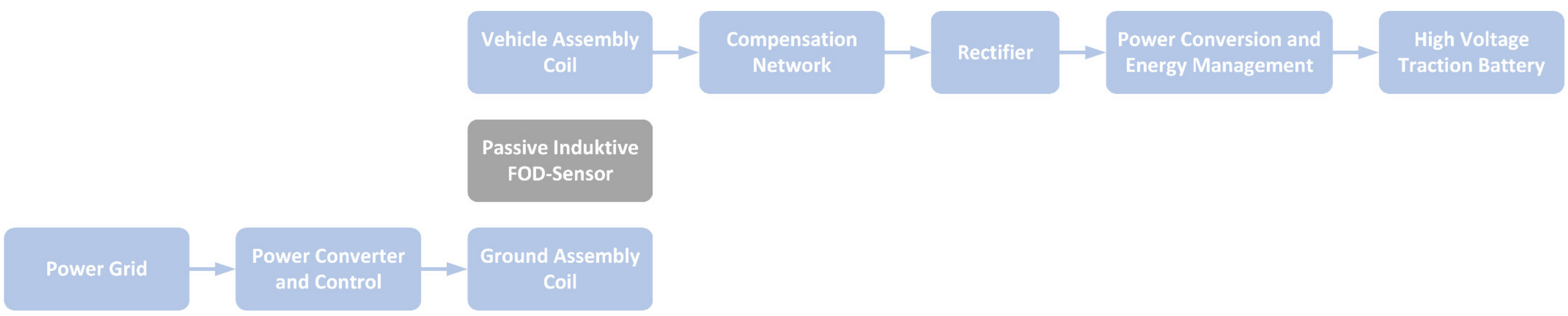

Figure 1: Components of a wireless charging system (blue) – ground assembly (bottom) and vehicle assembly with HV-battery (top) – and sensors for detecting metallic foreign objects (gray)

Benchmark scenario/mission/etc.

Metallic foreign objects heat up in the magnetic field mainly due to eddy currents and hysteresis losses. From the thermal behaviour of the foreign objects follows the risk during wireless charging if no appropriate measures, such as the foreign object detection, are taken. From the feedback effects of the foreign objects on the magnetic field of the GA coil and the characteristics of the sensor coils, it can be deduced how well metallic foreign objects can be detected at certain positions. From the viewpoint of the charging system and its safe use, in addition to the general appropriateness of the detection system, a functional check during the entire lifetime is also necessary in order to detect possible faults and failures and to be able to take appropriate action in response to them.

KPIs (related to requirements)	**Baseline**
• *Degree of detectability at different positions at the surface of the GA coil* *(At which positions relative to the GA and the sensor coil can test objects be detected?)*	• *Number of measurement points where the foreign object can be detected* • *Number of all measurement points*
• *Degree of detectability* *(How well does the sensor detect the test objects?)*	• *Output signal amplitude of the sensor with a specific test object* • *Output offset signal amplitude of the sensor without test object* • *Achievable accuracy with the measurement setup or the simulation model*

Evaluation

In terms of thermal behavior, the steel nail was the most critical of the test objects. Even at comparatively low field strengths, it was the fastest to reach temperatures above 300 °C and thus clearly exceeded the limits of the standardized test procedure (Figure 2). The 0.50 € coin, on the other hand, passed the test under the same test conditions — but also failed at higher field strengths.

The geometry of the sensor coils was improved with regard to the specific characteristics of the magnetic field of the ground assembly coil, so that the first KPI improved for the examined x-positions of the foreign objects from around 97 % for the conventional sensor design to 100 % (Figure 3). With the improved design, the detectability of the test objects was assessed for different positions and orientations with respect to the ground assembly coil and the sensor coils (Figure 4 and Figure 5). The accuracy achievable with the current system was used as reference for the assessment. The assessment results in two zones. In zone A, foreign objects in the charging system are detectable, whereby the detectability values are above 0 dB. In zone B, foreign objects are not or not reliably detectable — the detectability here has values less than or equal to 0 dB.

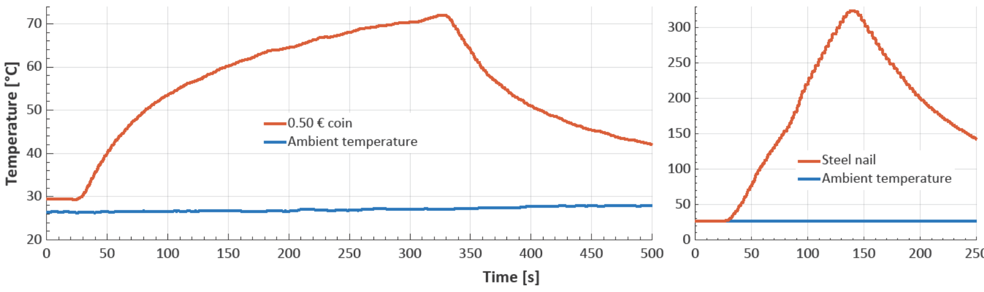

*Figure 2: Thermal behavior of test objects as a function of time at a current of 50 A rms in the GA coil (**left**) 0.50 € coin (**right**) Steel nail*

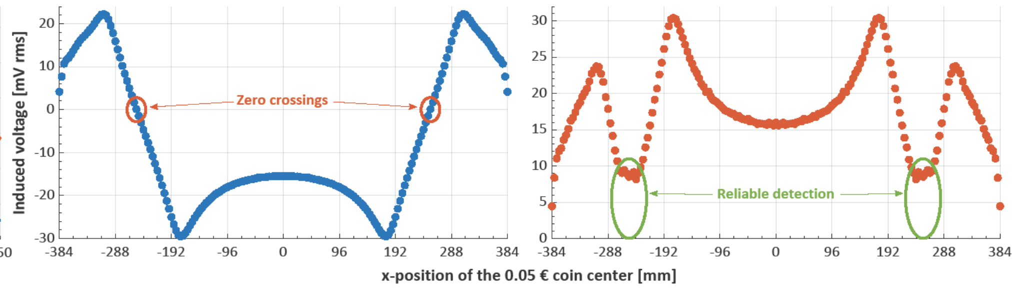

*Figure 3: Voltages induced in the sensor coils for different x-positions of the 0.05€ coin. (**left**) Conventional sensor coil (**right**) Improved sensor coil*

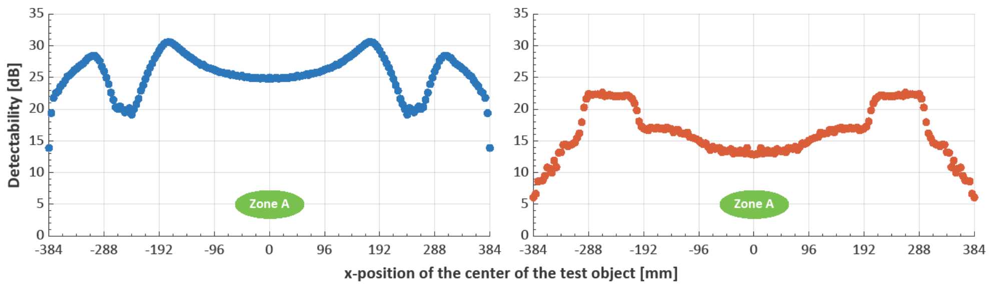

*Figure 4: Detectability of test objects with the improved sensor coil as function of their x-position. (**left**) 0.05 € coin (**right**) Steel nail*

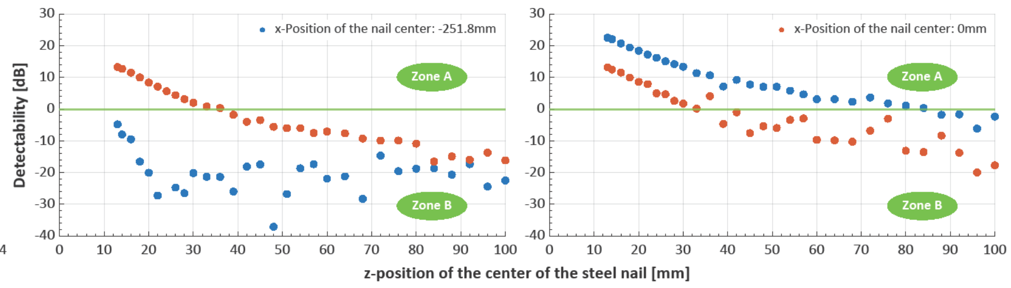

*Figure 5: Detectability of the steel nail as function of its z-position for two different x-positions. (**left**) Conventional sensor coil (**right**) Improved sensor coil*

Final status / Highlights

- Simulations and practical measurements on a real charging system's GA were carried out
- The experimental results were evaluated and assessed
- The general appropriateness of passive inductive sensors has been proven
- An improved sensor design was developed and presented
- The results were presented in two publications:
  - *Hentschel, U.; Labitzke, F.; Helwig, M.; Winkler, A.; Modler, N. Aspects of Foreign Object Detection in a Wireless Charging System for Electric Vehicles Using Passive Inductive Sensors. World Electr. Veh. J. **2022**, 13, 241. https://doi.org/10.3390/wevj13120241 (selected as Editor's Choice Article)*
  - *Hentschel, U.; Helwig, M.; Winkler, A.; Modler, N. Simulation of Foreign Object Detection Using Passive Inductive Sensors in a Wireless Charging System for Electric Vehicles. World Electr. Veh. J. **2023**, 14, 241. https://doi.org/10.3390/wevj14090241*

Impact

- *Evaluating the performance and safety of the sensor technology to ensure the safety of the power transfer in wireless charging systems*
- *Further development of the 2D and 3D simulation environment for wireless charging systems*

Used standards

- *SAE J2954:2020-10*
- *DIN EN IEC 61980-1:2021-09*
- *DIN CLC IEC/TS 61980-3:2021-10*
- *DIN EN ISO 19363:2021-02*
- *ISO 26262:2018-12*

Future standardization potentials

- *Currently, only procedures for fundamental tests for the appropriateness of the FOD system are standardized*
- *Requirements for the functional reliability and safety of FOD at runtime*

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