3rd Electric Road Systems Conference 2019
Frankfurt am Main, Germany, 7th to 8th of May 2019

Efficiency of AC conductive eRoad charging system – Analysis of experimental data

Mikael Hellgren[1], Nicholas Honeth[1]

[1]*KTH – Royal Institute of Technology, Stockholm, Sweden [surname]@kth.se*

Summary

Conductive charging systems will always incur losses in their operation. While conductive AC systems are relatively simple to model, the many parameters that must be taken into consideration can be difficult to quantify accurately. This work presents the experimental evaluation of one such conductive charging technology and aims to provide an exploratory analysis of the data gathered during evaluation and testing.

1 Research Questions

Where are the losses in an AC conductive eRoad Arlanda system and what are the magnitudes of the individual losses?

2 Methodology

The evaluation of the eRoad Arlanda project [1] is being performed according to a test specification developed in collaboration with the relevant authorities, including the Swedish Transport Agency, and the project partners. In addition to these tests an exploratory data analysis [2] is being performed in order to gain additional insight into the efficiency of the conductive charging system. The results of this analysis are presented in this work.

The conductive losses are calculated by comparing the AC power analyser data measured at the road-side feed and the AC input to the vehicle rectifier. The inverter is excluded for this evaluation due to the product-specific nature of these devices and that the analysis focusses on losses in the infrastructure specific to the eRoad concept. Future analyses will include all losses to the wheel when sufficient data has been collected.

Description of the system, sections, contactor stations

The in-road conductive charging system developed as part of the eRoad Arlanda has its origins in the Elways [3] technology illustrated in Figure 1. The eRoad Arlanda project is a consortium including infrastructure contractor, transport and logistics operator, postal service, electric distribution utility, a vehicle inspection company and an electric drivetrain specialist. Additionally, there are two research institutes affiliated with the project.

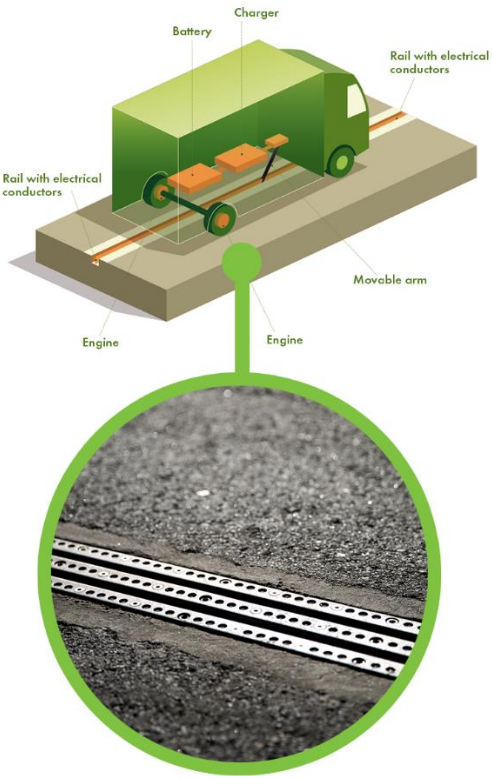

Figure 1: Conceptual illustration of eRoad Arlanda conductive charging system.

Since the autumn of 2015 the project has been in various testing phases with a first phase on a closed track. The second phase of testing on an open public road has been running since spring 2018 with a final round of *integration tests* performed during the autumn of 2018 before project was authorised to commence commercial operation.

Figure 2 shows the in-road rail charging concept which divides the conductive rail into 50m sections which are individually energised as the vehicle enters the section and disconnected once the vehicle has moved to the next rail section. The electric vehicle used is equipped with a conductive pick-up arm which actively finds and connects to the rail. The vehicle is equipped with on-board rectifiers to convert the 800VAC to ca. 630VDC used by the battery.

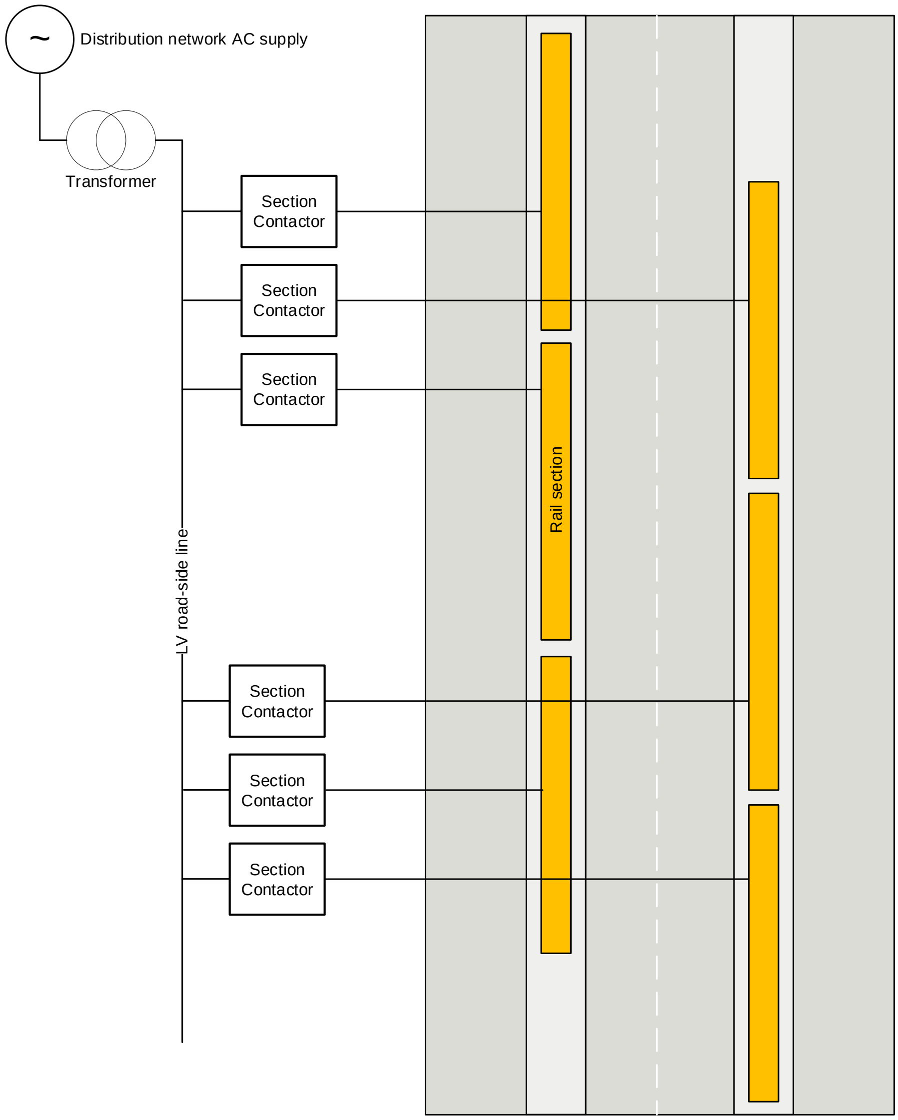

Figure 2: Block diagram of road-side components.

Description of the data collection

Starting with the integration tests and subsequent commercial operation, data has been collected from various loggers and measurement equipment integrated into both the eRoad and the vehicle.

Figure 3 shows the vehicle data collection system which comprises an AC power analyser, vehicle control system logger and cameras for road and pick-up video recording.

Examples of data collected are; AC voltage, current, phase angle at both the road-side contactor cabinets and the AC input to the vehicle rectifier. Switching events in the road-side contactor cabinets are recorded at strategic points for assessment switching sequence and validation of safety functionality.

Additional logging of both the vehicle and electric drivetrain controller area network (CAN) busses allow analysis of the vehicle status in relation to the charging operation on the road. Vehicle speed and position are also recorded. This data is collected in a time-synchronized database where it provides a basis for detailed analyses of both individual tests as well as aggregated performance over longer periods.

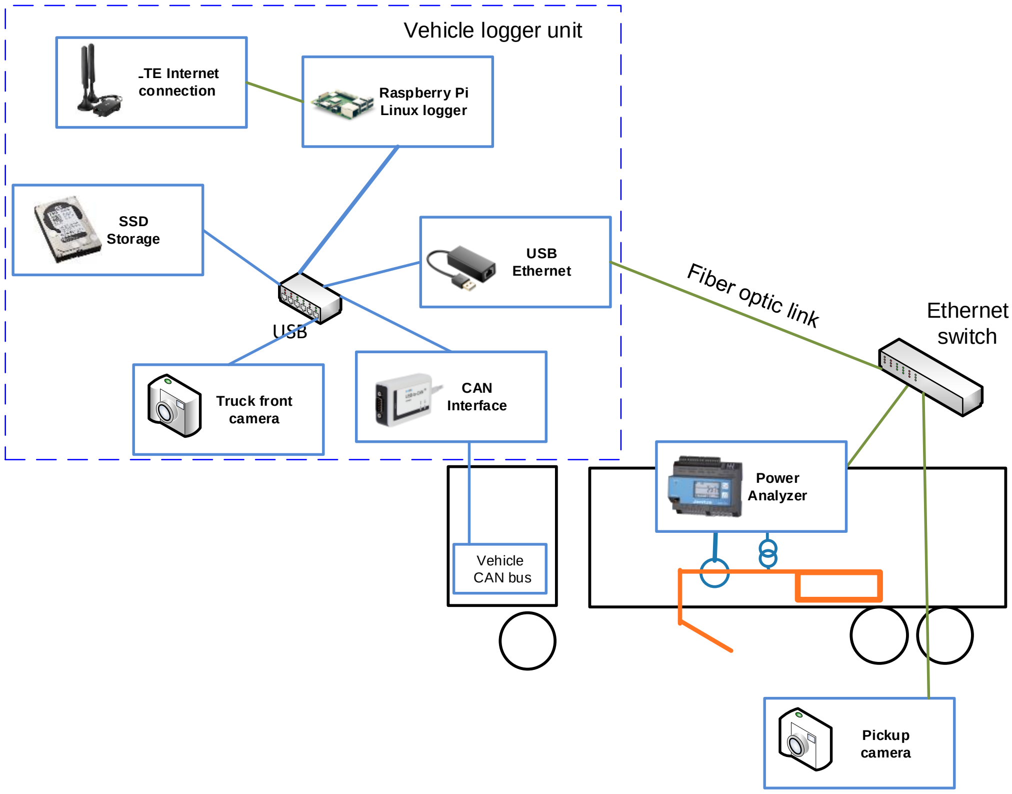

Figure 3: Overview of data collection system used for evaluation.

3 Results

Integration tests have been conducted during the period from 2018-10-19 to 2018-12-11. This extended abstract describes results from integration tests for the eRoad Arlanda system. Results to be presented at ERS 2019 will be based on longer time series collected during the demonstrator with commercial freight transport between Stockholm Arlanda airport, Sweden, and the postal terminal at Rosersberg. These tests are being performed during the spring of 2019. An application of these results is for planning an optimisation of cable lengths and dimensions as well as transformer station placement. Additionally, this work aims to provide a future basis for comparison between different ERS systems. A future goal is to develop and parameterise a model based on gathered test data for such purposes.

Preliminary results show an active loss of ca. 10kW at 160kW vehicle rectifier input. As the analysis will show, these losses vary with vehicle position, distance from transformer station, position on individual rail section as well as salt and contaminants in the rail.

Figure 4 shows the results of an individual integration test over 12 sections of the rail or about 600m of the track length with the vehicle travelling at 40km/h. Typical power factor values are in the region of 0.85. What also could be seen is a quite big drop in voltage at the contactor cabinet, this must be due to losses in the transformer. Looking at the power intake to the truck a quite stable active power is seen. The rectifier in the truck tries to put out a constant current to the batteries while the battery voltage is stable due to the big capacity of the batteries. Therefor a constant active power is reached at the input of the truck.

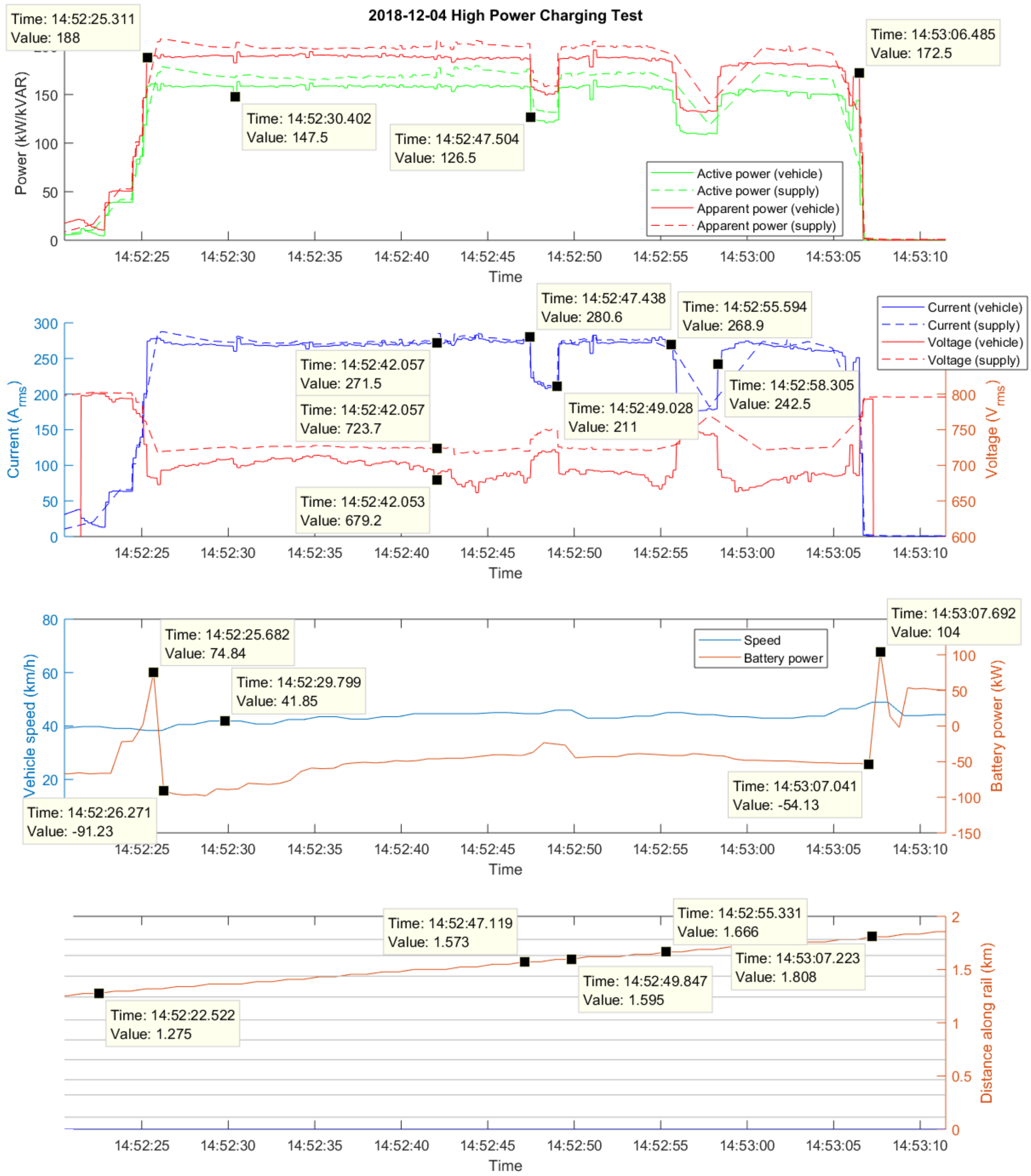

Figure 4: Time-series measurement of vehicle charging along 12 sections of the demo track.

Acknowledgments

The authors would like to thank our eRoad Arlanda project partners for their patient and committed support during the testing required for this work.

References

[1] eRoad Arlanda project, accessed 25 February 2019, <http://www.eroadarlanda.com>

[2] Antony J., *Design of Experiments for Engineers and Scientists*, 2nd Edition, 2014

[3] Elways, accessed 25 February 2019, <http://www.elways.se>

Authors

Mikael Hellgren is working at KTH Royal Institute of Technology at the department of Machine design within the unit of Mechatronics. Furthermore affiliated to the ITRL Integrated Transport Research Laboratory. Key areas are low energy consumption vehicles and electric roads. Working with tests of the Elways system sins 2015. Courses held is Robust Mechatronics, basic electronics as well as different project based courses in machine/mechatronics.

Nicholas Honeth is a researcher at KTH Royal Institute of Technology at the division for Electric Power and Energy Systems as the school of electrical engineering. Besides his research activities he is responsible for the Sustainable Power Laboratory where he facilitates a range of research projects in the areas of power electronics, machines and drives, electric power system simulation, control and automations systems.