Energimyndighetens titel på projektet – svenska Konceptstudie - Automatisk laddning av autonoma elektriska tunga fordon
Energimyndighetens titel på projektet – engelska Concept study - Autonomous charging of autonomous electric heavy vehicles
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Foreword

The concept study was conducted during 2021 by Einride and Siemens and has been co-funded by the Swedish Energy Agency.

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Sammanfattning

I denna konceptstudie har möjligheten att redan idag automatiskt ladda en autonom tung eldriven lastbil demonstrerats av Einride och Siemens.

Bristen på en pålitlig, kraftfull laddningsinfrastruktur för laddning av tunga fordon är ett av de största hindren för elektrifiering av godstransporter och med tillkomsten av autonoma fordon läggs dessutom en annan dimension till detta problem - laddningslösningen måste vara helt automatiserad. I aktuellt projekt har därför möjligheten att använda den prototyp för automatisk laddning som Siemens har utvecklat för laddning av Einrides autonoma fordon testats och utvärderats.

Utöver laddning under natten bör laddning av tunga lastbilar helst ske under tiden fordonen lastas och lossas och då gärna med hög effekt. Detta ställer höga krav på den teknologi som används, samtidigt som den måste passa i de begränsade utrymmen som ofta finns runt lastkajer. Det är även viktigt med standardiserade lösningar för att säkerställa en bred användning.

Projektet har identifierat en rad tekniska och operationella utmaningar som behöver adresseras inför ett större demonstrationsprojekt.

Summary

In this concept study, the possibility to, already today, automatically charge an autonomous heavy electric truck has been demonstrated by Einride and Siemens.

The lack of a reliable, powerful charging infrastructure for charging heavy vehicles is one of the biggest obstacles to the electrification of freight transport and with the advent of autonomous vehicles another dimension is added to this problem - the charging solution must be fully automated. In the current project, the possibility of using the prototype for autonomous charging that Siemens has developed has been tested and evaluated on Einride's autonomous heavy vehicle, the Einride Pod.

Besides overnight charging, heavy trucks should preferably be charged while the vehicles are being loaded and unloaded to ensure high utilization rate. This places high demands on the technology used, at the same time as it must fit in the limited spaces that are often found around loading docks. It is also important that the charging solutions used are standardized to ensure a wide range of uses.

The project has identified a number of technical and operational challenges that need to be addressed ahead of a more long-term demonstration project.

Background

One of the biggest challenges for a large-scale electrification of freight transport is the lack of a reliable, powerful charging infrastructure. In addition, since higher vehicle use is comparatively more important for an electric truck than a diesel-powered one, a safe and smooth charging procedure during loading and unloading is an important step in making electric trucks competitive in terms of cost. With the advent of autonomous vehicles, another dimension is added to this problem - the charging solution must be fully automated. Even if trucks are operated by a human driver, restrictions arise from the reliance on cable-based, human operated systems – for example, the charging procedure can often not be carried out by drivers due to labour legislation and has thus to be carried out by specially trained personnel.

The current project is a concept study on automated charging of autonomous electric heavy trucks. The project is a collaboration between the companies Siemens and Einride. Einride is a Swedish growth company in electromobility that combines the development of an autonomous electric heavy truck (Einride Pod) with the development of a software platform for planning, execution and analysis of electric freight transport. Siemens is a global technology company that invests heavily in the development of charging infrastructure. Siemens has developed a prototype of an automatic charger for electric vehicles.

The main purpose of this project has been to test and evaluate how the prototype for automatic charging that Siemens has developed can be used for charging Einride's autonomous vehicles. The goal is to identify the technical and operational challenges that need to be addressed before a major demonstration project.

Today, there exists various solutions for automatic charging for heavy electric vehicles, mainly through so-called pantograph chargers. Siemens was a leader in the development of this technology, which makes it possible to charge quickly and efficiently via a pantograph that comes down from a mast, connects to rails on

the vehicle's roof and charges conductively. Siemens today delivers state-of-the-art charging solutions based on this technology and this works very well for electric buses since they often have plenty of space on the roof for the rails to which the power transmission takes place. Since the associated position tolerance is quite large, the geometric dimensions of the contact system must also be large. Therefore, this solution is not suitable for electric trucks because of the limited space where the vehicles load and unload. An alternative solution is therefore needed here, and research and trials are underway on various solutions, such as inductive charging via a charging plate under the vehicle. Below is a short summary of different possible technologies, besides the pantograph mentioned above, that are relevant when talking about autonomous charging.

Wireless Power Transfer

Inductive power transfer between two coils (primary and secondary) at 85 kHz according to IEC 61980 / ISO 19363 / ISO15118-20. Current standardization is covering charging speeds of only 11 kW, but 22 kW is to be expected soon. However, inductive charging is not standardized for higher charging speeds which is necessary for fast charging during loading/unloading. The charging efficiency is around 94-96% but higher charging speeds would also lead to high charging losses. Hence, this solution is not optimal for fast charging of electric trucks, but more for slow charging overnight.

Automatic Charging Device Underbody (ACDU)

Automatic conductive charging system that connects a ground charging station with the underbody of the vehicle. This is a very interesting solution but there is currently no industry wide connector defined and the already existing charging plugs (type 2 or CCS2) cannot be used. Standardization for this way of autonomous charging is not expected within the next 10 years.

Autonomous Charging Device Side (ACDS) – mobile

Automatic conductive charging system that connects a standard charging plug (CCS1, CCS2, ChaDeMo, etc.) into the vehicle inlet from the side. The charging station is mobile (e.g. via an automated guided vehicle – AGV), carrying a battery, and is moving to the vehicle for charging (e.g. in a parking garage). The downside of this concept are the high costs for the AGV and the need for many batteries, as they need to be recharged constantly. Also, the mobile batteries, carried by the AGV, will not have sufficient capacity to fully charge an EV if the AGV is to be kept at a reasonable size. Thus several charging manoeuvres are required.

Autonomous Charging Device Side (ACDS) – stationary

Automatic conductive charging system that connects a standard charging plug (CCS1, CCS2, ChaDeMo, etc.) into the vehicle inlet from the side. This is the system that Siemens has developed and that has been tested in this concept study. The charging station is stationary, and the vehicle drives to the station.

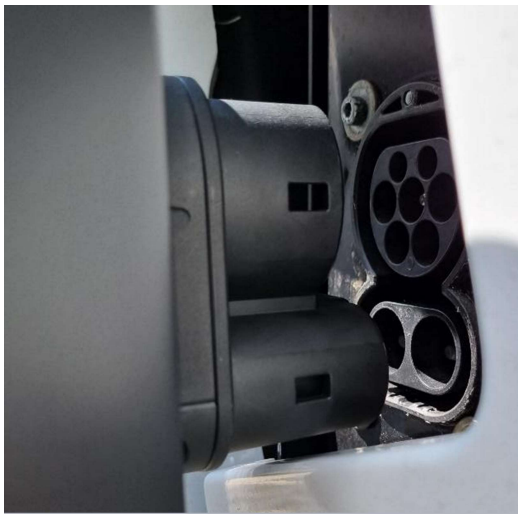

Figure 1 Close up of the prototype tested in the project

Another important topic is standardization which is key for interoperability. When it comes to the plugs a new standard, the MCS (Megawatt Charging System) plug, is expected to be finally standardized throughout 2023. The Siemens autonomous charging station is by its design already prepared to work with this new standard. Siemens is part of the CharIn pre-standardization discussions and is closely following the development/standardization process and a switch from the current CCS to the MCS plug is easily possible for the SIEMENS autonomous charging system.

Implementation

The new automatic charger from Siemens that has been tested in this project is a prototype that combines known technology from the existing charging portfolio with an automated robot arm that connects via a standard CCS2 connector. The development of chargers without manual torques is important both for increased automation and for easier handling of cables, especially for high powers. It is a great advantage to have a solution based on existing standards and communication protocols as it means that it will work together with the existing vehicle fleet and provides a greater opportunity for scalability.

The Einride Pod, that Siemens' solution has been tested on, is a new type of vehicle without a driver’s cab and is designed specifically for autonomous driving. In 2019, Einride was the first on the market with such a vehicle when it received permission from the Swedish Transport Agency to start commercial operations on a public road at a DB Schenker facility in Sweden. Since there is no driver, it is important that the charging can also be done automatically without manual steps. An automatic charging solution would further strengthen the incentive for Einride's customers to switch to automated transport, which is important for achieving the full potential of the solution provided by Einride.

The project consisted of three steps: Preparation of the test, Completion of the test and Summary of experiences.

Preparation of the test

This step included preparation of the test, both from a technical and practical view. The practical preparation included discussions on test cases and procedures for the test, as well as deciding on the site for the testing and staffing.

From a technical perspective the preparation included ensuring a stable connectivity and positioning of the Einride Pod. Furthermore, a prototype of a hatch on the Einride Pod covering the inlet that could be opened by the remote operator was developed.

Completion of the test

The companies conducted a joint testing event from 20.-27.08.2021 at the Siemens R&D centre in Munich, Germany. The Einride Pod was transported to Munich where it was unloaded and set up for the test. The test consisted of several different steps:

- Test drives for entering and exiting the Siemens Autonomous Charging Station (ACS)

- Testing of automatic vehicle identification by the ACS via artificial intelligence

- Testing of automatic inlet detection by the ACS along Einride truck via artificial intelligence

- Testing of automatic mating/unmating of the charging plug in/out of the Einride truck

- Several detailed charging tests incl. identification of charging issues via log files, ad hoc discussion of root causes and implementation of quick fixes

Summary of experiences

After the test, the experiences were summarized and discussed, together with the challenges that a longer test would entail.

Figure 2 **The Einride Pod on site at Siemens R&D centre in Munich, Germany.**

Figure 3 **The Einride Pod and Siemens Autonomous Charging Station.**

Results

The main result from the project is the demonstration of the two prototypes, showing that it is possible already today to achieve automated charging of an autonomous truck. The concept study has been valuable for both companies, providing a lot of learnings and insight into the challenges related to autonomous charging. Below are some of the key learnings from the project:

- How to ensure positioning of the vehicle, the accuracy needed to access the charger and what is required to achieve that.
- How the inlet of the vehicle can be detected and challenges around that
- Development of a prototype solution for a hatch on the vehicle that can be remotely opened.
- How to set up the automatic mating/unmating of the charging plug in/out of the Einride truck, time and the process required to do an automatic check that the cable is attached correctly and challenges related to that.
- How the charger can identify the vehicle using artificial intelligence

Discussion

The concept study has been very valuable and has provided great input on the possibilities and challenges when it comes to autonomous charging in general and the tested solution in particular. The tested solution proved to work well, although more long-term testing is needed to ensure stability and durability.

Within the commercial environment of a logistics application, the proposed solution has the economic advantage of reduced waiting times and thus increases the availability of the vehicle, which significantly increases its utilization rate. In environments where vehicle operations can be fully automated, the fully automated charging solution represents a crucial part of the overall system.

However, as mentioned previously, an important aspect in road freight transport is the opportunity to charge during the loading and unloading procedure. Given that loading bays are narrow areas it could be a challenge to fit the tested prototype in some loading bay areas and adjustments to the physical environment may need to be made.

Publications

The collaboration and the outcome of the test was presented in a joint session at the IAA Mobility 2021 in Munich[1]. Also, an article has been published on Siemen's website[2]. Further dissemination activities are expected during 2022.

[1] https://player.vimeo.com/video/601089250?h=789ca8480b

[2] https://new.siemens.com/global/en/company/stories/research-technologies/energytransition/autonomous-charging-system.html