

Parking support for inductive charging

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Summary

Inductive charging could give electric vehicles yet another competitive advantage over fossil-driven vehicles in that users seldom or never have to think about refueling. However, when about to recharge the vehicle, the secondary, receiver coil must be precisely positioned above the primary, transmitter coil in order to achieve high transmitted power and efficiency. Manually maneuvering a vehicle to this position has in our studies proven to be a challenging task, especially when using tight or public parking spaces. This article investigates the parking precision challenges connected with induction charging along with possible solutions, including fully automated parking.

Keywords: charging, wireless charging, user behavior, automated, EV (electric vehicle)

1 Introduction

Wireless inductive charging of electric vehicles could potentially change user behavior from “going somewhere to refuel” to “recharge whenever parked”, thus giving electric vehicles yet another competitive advantage over fossil-driven vehicles in that users seldom or never have to think about refueling. In earlier studies, presented at EVS29 [1] [3] and AHFE 2016 [2], users in fact stated that wireless charging could be attractive compared with manual conductive charging and there were also indications that the charging behavior most likely will change.

However, inductive charging requires that the secondary, receiver, coil has to be precisely positioned above the primary, transmitter, coil in order to achieve a high power transfer and efficiency. In the study, the users found this to be a hard task, especially since the charging equipment was mounted at the rear of the vehicles and even more so when using public parking spaces, despite the available guiding support. From a user perspective, the parking problem could be compared with the issues many people experience today when driving into a car wash. Thus, new solutions that can help the driver position the car sufficiently accurate for inductive charging are needed.

2 Need of precision parking

The charging transmission efficiency varies with both lateral and vertical position, see Figure 1 below from measurements of the efficiency of the Plugless[®] system mounted in a Nissan Leaf on an actual parking space in a garage, see [3]. During the measurements, the charging plate was moved in order to estimate how the charging efficiency varies with position as shown. As a starting point, the left rear corner of the parking slot was chosen. The charging plate was moved to a chosen position and the charger was turned on for one minute. The power analyzer was set to measure every ten seconds whereon the first and the last measured value of each position was excluded, and the average charging efficiency for the position was calculated based on the rest of the measured values. It can be seen in the figure that the efficiency is higher around the center, and when plotted on an X/Y-surface describing the lateral deviation from a perfect alignment exhibits a crater shape.

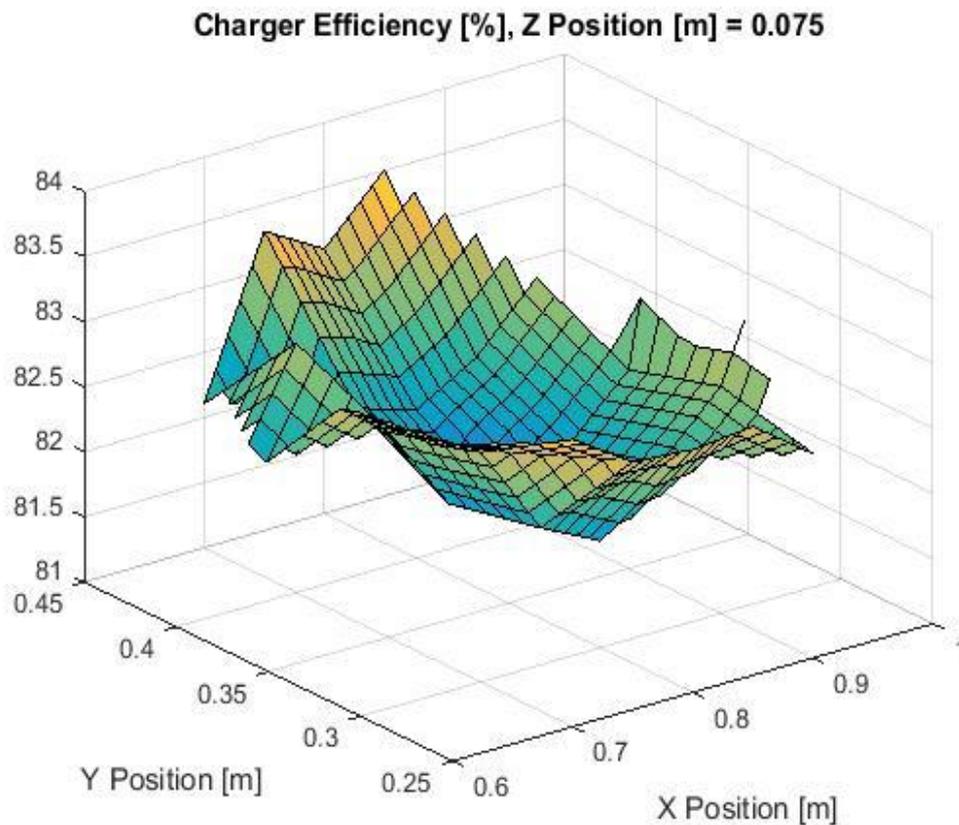


Figure 1: Charger efficiency.

The position tolerance for acceptable efficiency was in this case found to be a circle with diameter 25 cm. To help users position their vehicle within this area, the Plugless system offers a guiding system in the control panel mounted in front of the vehicle. The control panel is equipped with arrows indicating which way to move the vehicle when approaching the charging pad. The position of where the control panel is mounted relative to the approaching vehicle becomes very important; a poorly chosen location makes it hard to see the driving directions from the control panel. Other manufacturers have demonstrated user interaction using the car's dashboard display or through a handheld device like a smartphone.

A push from the vehicle manufacturers to decrease size, weight and cost of both primary and secondary coils leads to a smaller area where power can be transmitted successfully. This decreased deviation tolerance thereby leads to the driver being even more challenged to park optimally.

3 Experiences of parking for wireless charging

WiCh – Wireless Charging of Electric Vehicles – was a large-scale, 18-month user study of inductive charging, involving 20 vehicles introduced in existing vehicle fleets to be tested by its users in their ordinary work in Sweden. More specifically, the equipped vehicles were used by municipality representatives in daily operations for transportation purposes (except for one vehicle, which was used by a private user). Typically, the vehicles were parked in parking garages, often in tight spaces. The vehicles were distributed over 8 different sites in the south of Sweden, in the cities of Stockholm, Uppsala and Gothenburg. The user group did not possess the characteristics of early adopters (people using new technology as soon as it's available) since the participation of the drivers has not been on a voluntarily basis but rather chosen by the organization they work for.

The user study consisted of 4 digital surveys complemented by interviews and logging of vehicle movements. The first digital survey (Q1) (N=65) was distributed to the users in May 2015, before the introduction of inductive charging. The second survey (Q2) (N=56) was distributed approximately two months after the installation of the inductive charging equipment, the third survey (Q3) (N=44) about four months after installation, and the fourth and final survey (Q4) (N=45) about 12 months after installation. The survey focused on capturing changes in attitudes and the user experience over time. Here, we focus on presenting the results of a selection of questions from the digital surveys related to the experience of parking.

In general, the majority of the participants in the study considered inductively charged EVs to be an attractive means of transport. At least equally attractive to charging with cable, see Figure 2.

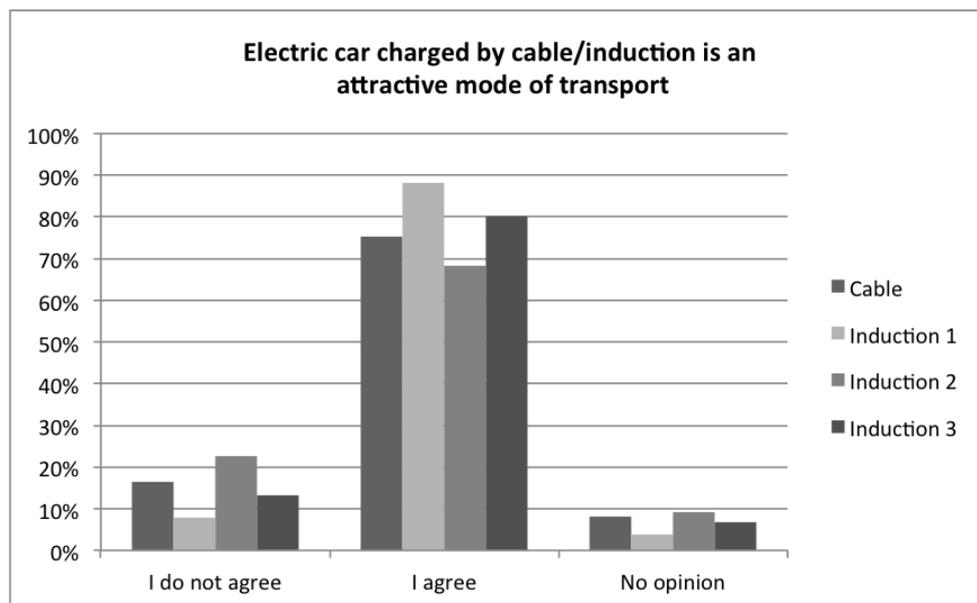


Figure 2: Users' view on charging.

It was also indicated that the charging behavior has a potential to change with inductive charging, while the perceived minimum parking time for drivers to be motivated to start the charging tends to be lower for inductive charging (Figure 3). However, many of the respondents have no opinion on the matter. One interpretation of this is that inductive charging has a potential for a more frequent connection to the grid also during short stops, if inductive charging is available.

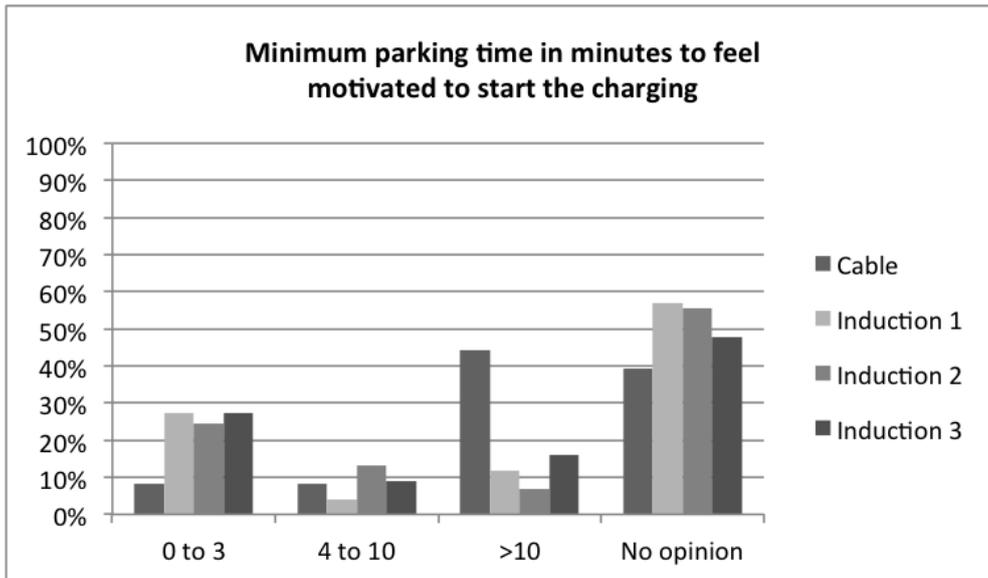


Figure 3: Minimum perceived parking time to feel motivated to start the charging. Some respondents feel motivated to start charging at shorter parking times as compared to charging with cable, however many have no opinion.

The survey also pointed out that parking is an important area to further study and improve, since there is a radical change in opinion towards the negative side regarding the need to park accurately when using induction. When asked to freely state what they perceived as the hardest part of charging with induction, more than half of the participants stated issues related to parking (e.g. “it is difficult to park correctly in relation to the charging pad”, or “you have to park several times to get it right”). This stands in contrast to the same question in the first survey, “which is the hardest part of charging with cable”, where none of the sixty-one answers mentioned parking issues, see Figure 4.

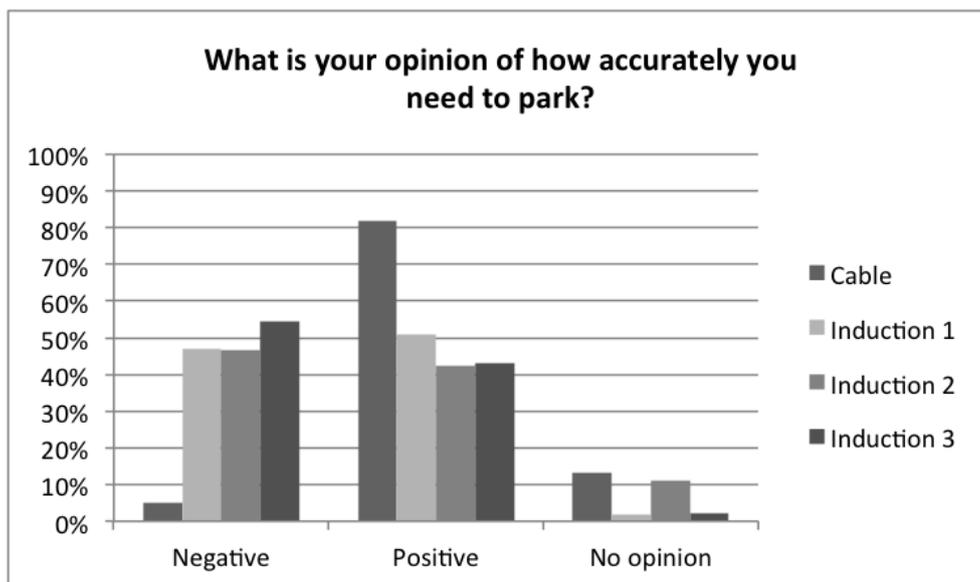


Figure 4: Users’ view on parking precision.

The participant surveys in the study indicate that inductive charging has the potential to contribute to a positive experience of EV charging. However, there is a need to look closer at parking precision. Especially

the ease of use regarding parking and starting the inductive charging process should be further addressed. For example, the support for parking with sufficient accuracy could be improved or the inductive technology made less sensitive to vehicle positioning. The remainder of this article further explores the need for parking precision and suggests automated parking as a possible solution to enhancing the user experience of inductive charging.

4 Parking precision study

There could be several reasons for the problems that the users experienced. In the WiCh project, the vehicles were equipped with Plugless[®] aftermarket solution, mounted at the rear of Chevrolet Volt and Nissan Leaf vehicles. Positioning the rear of a vehicle equipped with front wheel steering is often perceived as hard for many drivers. Even with the help of the charging system's integrated positioning guidance system available in the control panel in front of the vehicle users perceived positioning as hard. Early users of induction charging of private cars probably have the systems installed at home and at the most convenient place and where they quickly learn how to park and position their cars. But for fleet users like the ones in this study, who maybe drive different cars, not all of them equipped with inductive charging, and also have not volunteered to use the systems, the positioning issue could be even more emphasized. It can be compared with the issues many people experience when positioning the wheels onto the conveyor belt as they drive into an automatic car wash. It is not uncommon for some to avoid using automatic car wash machines for this reason.

In order to determine the need for parking assist, a study was made to create an autonomous measurement system capable of capturing vehicles' relative position within a parking space [4]. Using a time-of-flight camera coupled to a support vector machine classifier not only the position of the car, but also its dimensions and orientation within the parking lot was determined, see Figure 5.

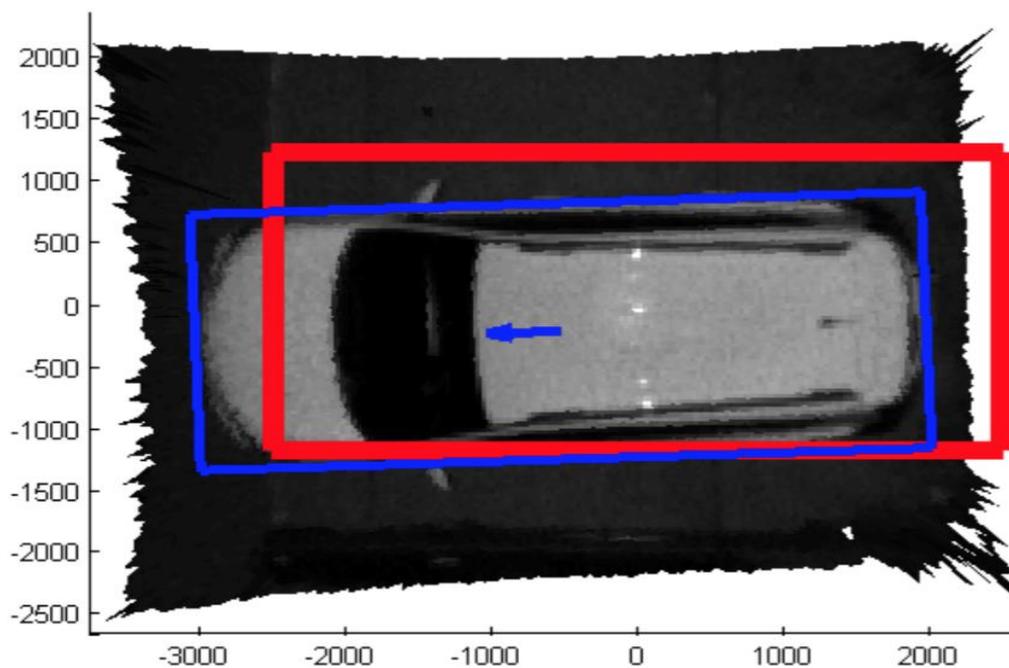


Figure 5: Generic view on parking precision.

Figure 6 below shows a diagram of the state machine used to control the Time of Flight (ToF) camera.

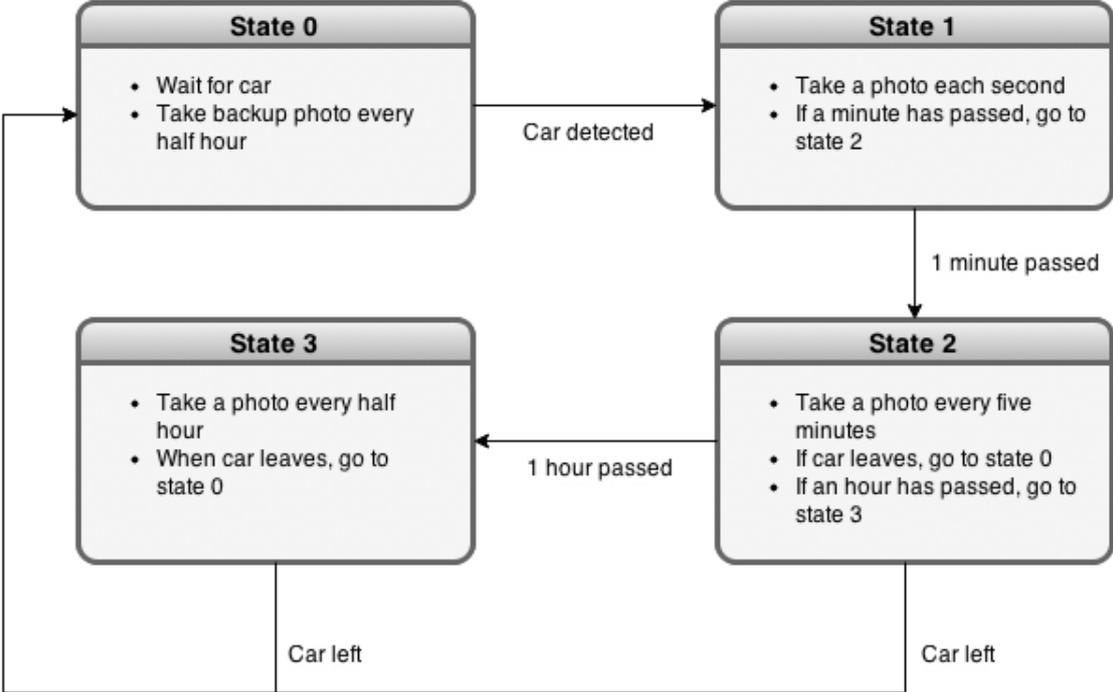


Figure 6: Simple diagram of the state machine used to control the ToF-camera.

The study points out many interesting findings, but the general conclusion is that people park their car quite differently. People typically position the front of the vehicle within a tighter area than the rear, see Figure 7 where a subsection of parked cars’ center point between the front and rear wheels have been plotted. This seems natural, considering both that the front wheels are steered and that the driver in general has a better view forward than rearward.

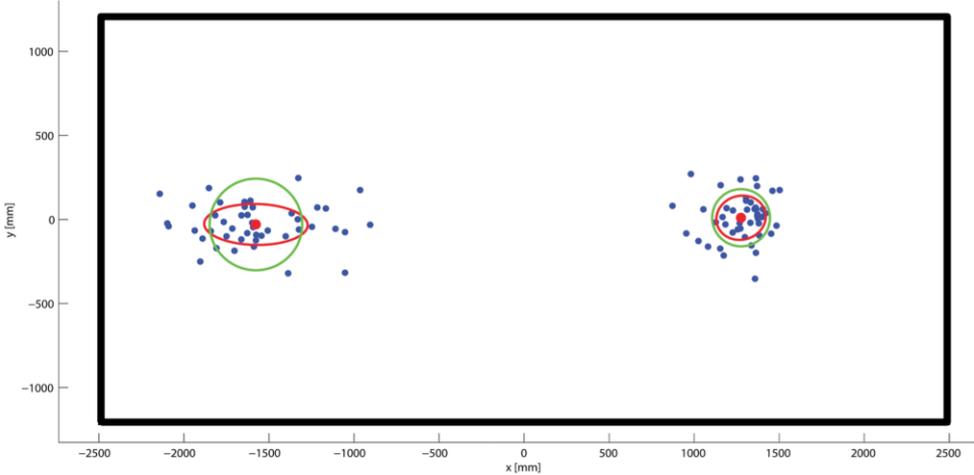


Figure 7: Variations in front (dots to the right) and rear (dots to the left) axle center positions.

Based upon this, it seems that the best location for mounting the secondary coil would be at the front of the vehicle. However, at least for hybrid electric vehicles, the space at the front end of the vehicle where such a system can be mounted is very limited. To mount the equipment at the rear is often much easier. Regardless of which, both types can be accommodated by a parking place with a charging pad at one end, even if one of the types of cars would have to back in, leading to the wider spread in positioning as shown in Figure 7.

A third alternative would be to mount the charging equipment in the middle under the car, which could also give a better shielding of magnetic fields associated with the charging equipment. This would make it possible to both drive and back in the car, but also this space under the occupant's feet is very tight. Even if not evaluated in this study, it can be expected also to be hard to position the mid of the car manually over a specific spot. equipment.

5 Automated parking

Considering the issues that many drivers have with parking, integrating induction charging together with automated parking seems to be an optimal solution. An illustrative picture of how it can look at a house with home charging with induction is given in Figure 8. Several car manufacturers already offer automated parking systems, where the car detects a free parking space and performs the steering maneuvers necessary to correctly position the vehicle; but the driver maintains control of the speed.

In the future, these systems can be expected to evolve to fully autonomous parking, without the need of a driver present. Such systems could then also allow for cars being sent away to park and when needed summoned back. In this scenario, automatic charging is all but required since there at the parking lot, most likely, will be no-one present to plug in a cable.

The user interaction concept for the combined parking/charging system has then to be carefully designed:

- The parking and charging procedure should be fully automated.
- The vehicle should park itself in a position that is optimal for charging, without hurting or damaging any other objects.
- The user should be able to with a user-friendly interaction control the procedure, either from inside the car using a touch screen or similar device, or from outside using a mobile phone or the vehicle's keyless entry system.



Figure 8: An illustration of home charging with induction.

A typical use case would be the following. The driver requests “Park”. The vehicle's display will then show available parking spaces in the near vicinity, including which of these that are equipped with inductive charging systems, or for that matter also those with conventional cable charging. The driver selects a desired parking space. The vehicle then parks itself and charging starts. Charging stops automatically when the battery is fully charged; if the vehicle is started; if the driver directly requests to stop the charging. If the

driver has requested some other function requiring an external power source, for instance pre-heating or pre-cooling the energy transfer would still be maintained despite the main traction battery being fully charged.

These future autonomous parking systems share the need with induction charging systems to detect objects under the vehicle; for induction charging to avoid exposing living objects to strong magnetic fields; for autonomous parking to avoid running over objects when self-parking or being summoned.

6 Discussion

As shown above, the challenges experienced by the driver related to positioning the vehicle optimally over the induction charging pad can be overcome if the charging system is integrated together with an automatic parking system. This combination, even if initially offered as an optional support system, will become a necessity when inductive charging components decrease in size.

Thus, when developing future autonomous parking systems, consideration should be taken already from specification to include positioning for inductive charging.

Acknowledgments

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Authors



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