MyTukxi: Low Cost Smart Charging for Small Scale EVs

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ABSTRACT

As the electrification of the transportation sector grows the electric grid must handle the new load resulting from electric vehicles (EV) charging. The integration of this new load in the grid has been subject to work in the smart-charging research field, however, while normal-sized EVs often offer chargers or other functions that support smart-charging, smaller EVs do not, which could be problematic. Especially considering that the consumption of small EV when aggregated can be significant. This

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article presents the motivation and development behind the development of MyTukxi, a hardware and software system that aims at implementing smart-charging algorithms for low consuming electric vehicles (EV), interacting with drivers to compensate for the lack of charging control in such vehicles.

INTRODUCTION

Transportation is one of the main fields responsible for global CO2 emissions and therefore climate change, nowadays the global transportation sector is responsible for 23% of the global emissions [4]. This issue has been addressed in the different sub sectors from aviation, shipping and land transportation. Regarding road transportation, there is a clear effort from manufacturers and government to promote alternative and cleaner solutions for the internal combustion engine (ICE), namely the electric vehicles (EV). Besides being cleaner, EVs also provide other advantages to end consumers, such as lower running costs (charging and maintenance) or lower noise [5]. These factors combined resulted in a surge in EVs adoption [4]. This growth will surely present new challenges to the electric grid since the charging of EVs will result in a new load that must be met without harming the other services offered by the grid, while still providing EV drivers with the desired charging when needed. Solutions for this challenge fall into the scope of smart-charging, which can be defined as a set of techniques that control the charging of EVs based on factors such as the price of electricity, availability of renewable energy or expected route [11]. It is common for manufacturers to include smart-charging functionalities in their vehicles/chargers [1, 9]. However, smaller vehicles like scooters, bikes, forklifts or golf carts normally do not offer these functionalities, and even though their individual impact on the grid is small, when aggregated the impact can be significant and unpredictable. Especially if we consider that small EVs are one of the proposed solutions for the 'last mile mobility and transportation problem [6]. Therefore, we argue that smart-charging techniques should be implemented to help control the aggregated charging of smaller EVs. As an example, a household/business with 5 electric scooters and 2 small EVs such as the Renault Twizy can require up to 7 kW off instantaneous power which is a significant load, especially in a small installation. [7, 10]. Furthermore, having the consumption divided among a lot of vehicles can difficult the prediction of power and range need.

RELATED WORK

Smart-charging is an established research field, most of the efforts in this field are focused on developing the appropriate algorithms to modulate the charge of EVs. Zhile Yang et al. [11] provides an extensive review of such methods, in general, there is no optimal approach, an algorithm effectiveness is closely coupled with the scenario that is being applied, for example, its computational cost, the available data, and limitations of the grid and EV's hardware. Other researchers are focused in the hardware side of smart-charging, developing systems that can be installed in the electric grid and implement the output of the smart-charging algorithms (e.g. [8]). These are often two distinct fields,
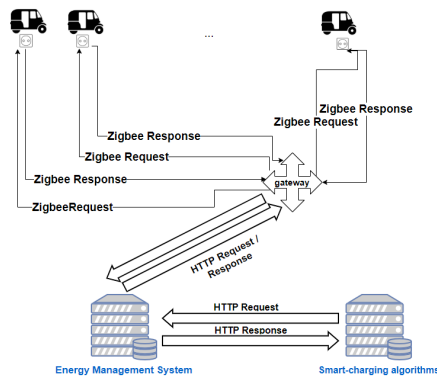
machine learning and mathematics researchers mostly work in simulation environments (e.g. [2]), while researchers working in the hardware to communicate with and charge EVs not always implement the state of the art smart-charging algorithms [8]. This is, of course, understandable, since there is no available charging infrastructure to test the more complex algorithms, and similarly the state of the art hardware development does not take into account the most complex algorithms which could be implemented.

This paper presents the MyTukxi System a software/hardware solution to control the charging of a fleet of electric scooters, the solution presented here can be generalized to any type of small EV's, or to bigger EV's charging at lower rates and/or without any type of charging control. The proposed system architecture separates the implementation of the algorithm in a different module which can run remotely allowing the easy integration of smart-charging algorithms in a real work scenario. We also present initial results of the deployment in a small sightseeing tours business in a tourist destination in southern Europe. The work presented here was highly motivated by the work of Iwabuchi et al [3] which proposes a system directed at individuals who park the car at big shopping centers, Iwabuchi et al system uses a terminal application installed in a smartphone to interact with it also uses a model to recommend charging schedules for the driver, however, the authors do not state how the actual charging is controlled.

MYTUKXI LITE SYSTEM

The MyTukxi system is composed of a set of off-the-shelf and custom made software and hardware components, the components were selected with the following objectives: 1. Measure individual, per vehicle, and aggregated EV charging consumption 2. Control each individual EV charging, 3. Estimate the state of charge (SoC) whenever an EV is plugged in or out of the electricity 4. Estimate the distance covered by the EV between charges 5. Expose the consumption, routes, and charging commands in an online server. Figure 1 presents a simplified scheme of the communication between the hardware, software and 3rd party components.

The hardware

In this section we describe the hardware needed to accurately measure and actuate on each EV electricity consumption:

Smart plugs: Each charging point contains a smart plug which can sense the electricity consumption of the devices connected and it can also be remotely turned ON/OFF. The smart plug is placed inside a box which transforms the connection from CE16 to schuko. Each plug is also uniquely identified by a number and QR code. Figure 2 shows how the components are assembled to correctly connect to the scooter charging cable and the charging infrastructure. Figure 4 highlights how these components are placed between the vehicle and the electrical installation.

Figure 1: Simplified scheme presenting the communication between the different software and hardware components of the MyTukxi system

Figure 2: Assembly of the components needed to measure and control the consumption, the CE16 male and female sockets are position towards the outside of the box, and the smart plug is placed inside
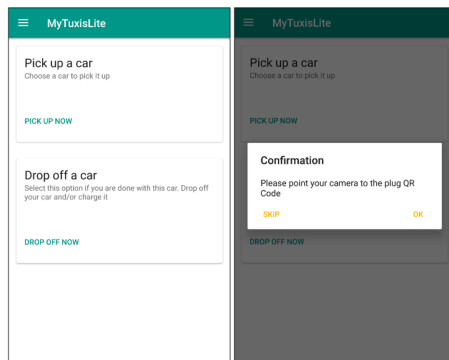
Figure 3: Different screens of the MyTukxi mobile application. Left: Home screen with the two main options picking up and dropping off a scooter. Right: Message asking the user to scan the QR code on the plug

Energy meter: A 3-phase commercial energy meter is used to measure the total consumption from the charging infrastructure. This aggregated information is more accurate than simply summing the consumption of each plug.

Gateway: The gateway is a microcomputer, with custom hardware/software. It communicates with each plug through a Zigbee mesh, this communication is composed of consumption points and ON/OFF commands. It also reads aggregated consumption from the energy meter described in the paragraph above. The gateway is also responsible to push individual and aggregated consumption information to the back end, and to forward ON/OFF commands from the back end to individuals plugs (and therefore vehicles).

The software

Apart from the components described above a set of software components also had to be developed in order to implement the interaction with the user and smart-charging algorithms, and to properly integrate the hardware components.

The mobile application

To facilitate the collection of the driving habits (which is an important input for the smart-charging algorithms) a mobile application was developed, this application is installed in the mobile phone of each EV driver, Figure 3 presents two different screens of this application. Before disconnecting the scooter from the electricity, plugging it in and at the start/end of each drive cycle, the application asks the user to input the battery SoC. This is a simple 1 to 10 number, normally low powered EV's have some sort of display of battery status, and we expect the drivers to input that information into the mobile application. The mobile application also uses GPS to provide an estimation of the number of kilometers the EV has traveled between each charging cycle. Lastly, the mobile application allows the driver to identify which EV is connected to which plug. This is done using QR codes at the plug and at the vehicle in this process the driver must first identify the vehicle and then the plug (using the mobile phone camera) see Figure 3.

The back-end infrastructure

At the back-end of the MyTukxi system there is a Node.js server that communicates with the gateway presented above, and with 3rd parties through an HTTP interface. The server offers web-services to: 1. Authenticate a driver/developer, 2. List all drivers and its actions (pick-up and drop off), 3. List all plugs and actions in the plugs (start charging and stop charging), 4. List all the cars, its actions (pick up/drop off), battery and trips, 5. List all the coordinates covered in each trip. 6. Turn a plug ON or OFF. With these services, it is possible for a smart-charging algorithm to run entirely separate from

the MyTukxi system. In this scenario, the algorithm uses the API endpoints to read for example the consumption and/or the battery SoC and then actuate into the loads by turning the plugs ON or OFF.

CASE STUDY - TUKXITOURS

A study is underway focused in a local business that provides small guided tours in Portugal. The business is called TukxiTours, and it operates in the downtown of Funchal. TukxiTours operate a mix of electric and gasoline-powered Ape Calessino scooters. In the scope of this pilot, only the 6 fully electric scooters are considered. Figure 4 presents two of the scooters charging. The Ape Calessino scooters have a 6.88 kW/h battery and are limited to charging at 16A. In practice, and based on the collected data, the most instantaneous power extracted by a scooter was approximately 2700 W.

Usage scenario

In a normal scenario of using the application a driver uses the phone and reads the plug QR code, then it reads the scooter QR code, afterward the user is asked to input the current battery level of the scooter (a value from one to ten as displayed in the scooter). From that point onwards the system will be recording the user GPS coordinates. Before starting a trip the system asks the driver to input the current battery level, and to indicate which trip is about to start (from a list of pre-defined trips offered by TukxiTours). Similarly, at the end of the trip, the driver is asked to input the scooter battery level. At the end of the day or when the battery is completely depleted the driver plugs the scooter at to the socket, and repeats the reading of the QR codes and input of the battery SoC process.

Preliminary study

Currently, all the hardware/software infrastructure described in the sections above is deployed, and 3 drivers from the TukxiTours are using the mobile application to track the electric scooters usage. In this initial period, the main goal is to test all the components and its integration. So far the system has logged approximately 25 trips and 60 battery status. Furthermore, in this period interactions with the drivers allowed us to gather inputs important to design the mobile application described previously, it also allowed us to better understand TukxiTours needs for the smart-charging algorithms. More concretely in a workshop with its drivers, we learned that: 1. Sometimes the scooters need charging in the middle of the day, 2. The drivers use a Whatsapp group to inform which scooters are available, being used or charging, 3. The scooters should be unplugged when the battery is fully charged otherwise the battery could malfunction; the drivers need to keep a record of all the distance traveled daily.

Figure 4: Charging infrastructure of the TukxiTours business with the MyTukxi hardware installed (highlighted at red)

CONCLUSION AND FUTURE WORK

In this paper we presented an inexpensive smart-charging hardware and software solution for EVs charging at lower rates. The system implements all the communication and control of the vehicles being charged allowing the smart-charging algorithms to run in a different module. This system is currently deployed in a small business, gathering baseline trip, charging and consumption data which will be used to build the smart-charging algorithms. Future work includes the implementation and evaluation of the smart-charging, which will take into account factors such as economic benefit, driver and management satisfaction. Although the work is still ongoing we believe there are three important contributions so far. Firstly, we proposed a system mostly based in off-the-shelf components that can be inexpensively used to implement smart-charging in vehicles which normally do not offer this service. Secondly, the proposed architecture, separating the smart-charging algorithms from the control infrastructure allows to offer algorithm researchers with an easy way to access real-world data and test solutions. Lastly, we overcome the technical limitations of small EVs by including the drivers into the system, gathering information normally not provided by smaller and cheaper vehicles.

REFERENCES

[1] BMW AG. 2018. Electromobility/charging : Home charging. https://www.bmw.com.mt/en/topics/fascination-bmw/electromobility/home-charging.html

[2] A Andreotti, G Carpinelli, F Mottola, and D Proto. 2012. A review of single-objective optimization models for plug-in vehicles operation in smart grids part ii: Numerical applications to vehicles fleets. In *Power and Energy Society General Meeting, 2012 IEEE*. IEEE, 1–8.

[3] Shigaku Iwabuchi, Soh Masuko, and Junichi Hoshino. 2013. Energy management system for electric vehicle based on user behavior induction. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*. ACM Press, Paris, France, 1671. https://doi.org/10.1145/2468356.2468655

[4] KB Naceur and JF Gagné. 2016. Global EV outlook 2017. *International Energy Agency (IEA): Paris, France* (2016).

[5] OFFICE of ENERGY EFFICIENCY & RENEWABLE ENERGY. 2016. Electric Vehicles | Department of Energy. https://www.energy.gov/eere/electricvehicles/electric-vehicles

[6] Samantha Raphaelson. 2018. Dockless Scooters Gain Popularity And Scorn Across The U.S. https://www.npr.org/2018/08/29/643058414/dockless-scooters-gain-popularity-and-scorn-across-the-u-s

[7] Renault. 2018. Charging, range | TWIZY | electric car. https://www.renault.qa/vehicles/new-vehicles/twizy/recharge.html

[8] M. A. Ruiz, F. A. Abdallah, M. Gagnaire, and Y. Lascaux. 2013. TeleWatt: An innovative electric vehicle charging infrastructure over public lighting systems. In *2013 International Conference on Connected Vehicles and Expo (ICCVE)*. 741–746. https://doi.org/10.1109/ICCVE.2013.6799888

[9] Renault SAS. 2018. Z.E Services - Apps on Google Play. https://play.google.com/store/apps/details?id=com.renault.android.myze&hl=en_US

[10] Xiaomi. 2018. Mi Global Home. https://www.mi.com/global/mi-electric-scooter/specs/

[11] Zhile Yang, Kang Li, and Aoife Foley. 2015. Computational scheduling methods for integrating plug-in electric vehicles with power systems: A review. *Renewable and Sustainable Energy Reviews* 51 (2015), 396 – 416. https://doi.org/10.1016/j.rser.2015.06.007