Development of the Web Platform for Management of Smart Charging Stations for Electric Vehicles

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Abstract: Shortage of fossil fuels and ecological thinking leads to shift in technologies for vehicle production. In the future only electric vehicles (EVs) would be produced. This will lead to huge increase in number of EVs worldwide, so it would be crucial to provide a broad public charging infrastructure. This paper exactly concentrates on the essential role of infrastructure in the mass implementation of electric vehicles. A focus is placed on sharing the residential infrastructure for public usage. Paper describes authors developed Web platform for sharing the information about privately owned charging stations, describing the additional option to link station hardware with software for real-time charging data and station availability updates. Developed platform brings together drivers of EVs and owners of the infrastructure. Developed platform is built like an interactive map, based on Google Maps service. Together with software part, authors developed also hardware, which is one Microgrid based on renewable energy sources with EV charging station functionality.

1 INTRODUCTION

Usage of electricity for car motors is becoming more popular nowadays and many European countries made considerable efforts to increase a share of electric vehicles (EVs) in the transport sector (Morrissey et al., 2016). There are two main reason for that: a) huge increase in the usage of non-renewable energy resources can possibly result in their depletion (Berjoza and Jurgena, 2015; Xiong et al., 2015); b) ecological aspects (climate warning) should be taken into account, as EVs move pollution away from urban areas (Hawkins et al., 2013). Electric vehicles has many advantages like emission free (Hess et al., 2012), energy efficient, and noiseless mean of transport (Hatton et al., 2009; Ruzmetov et al., 2013). Rapid growth of EVs is connected to notion of Smart cities (Schneider et al., 2008) and to the fact, that several countries announced ban of fossil fuel vehicles.

The worlds largest car market just announced an imminent end to gas and diesel cars, as a Chinese official told the audience at an auto forum in Tianjin that the government is working on a timetable to end production and sales of traditional energy vehicles (*https://www.vox.com/energy-and-environment/2017/9/13/16293258/ev-revolution*). Norway plans to completely ban petrol powered cars by year 2025 (*http://www.independent.co.uk/environment/climate-change/norway-to-ban-the-sale-of-all-fossil-fuel-based-cars-by-2025-and-replace-with-electric-vehicles-a7065616.html*). Aside China and Norway such countries as Netherlands, India, France, Great Britain, Germany and others plan to stop production of gas and diesel vehicles. It means that in our near future only EVs will be produced. This will significantly increase the number of EVs on the roads and infrastructure should be ready for comfortable usage and charging of EVs. Already today number of EVs is greater than 1200 thousands.

Figure 1 shows worldwide number of battery electric vehicles in use from 2012 to 2016 (in 1,000s) (*www.statista.com*). But situation with EVs varies among countries, for example in Latvia there are only 313 electric vehicles registered (*https://csdd.lv/statistika/transportlidzekli/*). Most of them (184 EVs) appeared on the Latvian roads in year 2014, when it was possible to use European Union funds for car purchasing. Unfortunately, nowadays this number is not increasing, mainly because road infrastructure is not ready. In Romania situation is rather similar, where less than 400 EVs are registered to this moment.

Due to mentioned facts and increase in EVs worldwide, it is important to provide a public charg-

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ing infrastructure that adequately caters to the needs of all EV users (Morrissey et al., 2016). One of the electric vehicle charging station demands is geographical dissemination (Berjoza and Jurgena, 2015) and availability, which can be achieved by relevant number of charging stations. Charging patterns and available charging infrastructure have a large impact on the way in which people use EVs (Hatton et al., 2009). The distribution of charging stations determines EV drivers accessibility to energy sources, and consequently affects the EV flow and traffic conditions in the road network (Xiong et al., 2015). EVs can be charged not only at public commercial charging stations, but also at residential houses (Xiong et al., 2015; Hess et al., 2012; Tushar et al., 2014; Schroeder and Traber, 2012), and sharing such private charging plugs could be good alternative to commercial stations.

Aim of this paper is to propose approach to easily share available private EV charging stations by using Web platform, where everyone can find, add and view privately available charging stations. Main advantage of proposed system is option to ensure real time data updates by linking hardware of charging station (including, but not limited to data about station availability, amount of available power, price for the charging, etc) with user friendly Web platform. Development and implementation of authors proposed system can facilitate usage of EVs in countries, where EVs are not very popular to this moment (e.g. Latvia and Romania).

There are several charging station maps already available online or by a mobile application. Examples are: *www.plugshare.com*, where users can view charging stations from all around the world, stations can be public or residential (private). Also system has user registration option to use all of the system functions (like adding of station, making and sharing reviews, view residential charging station details, etc).

Next example is *https://openchargemap.org/*. It is the global public registry of electric vehicle charging locations. Functionality is similar to previous one, additionally users can use many filters by searching for charging stations.

https://chargemap.com is another solution to see charging stations with option to determine which stations are the most relevant to use on your route. Access to the system is only by registering and log in. As well mobile applications are available for download.

https://ev-charging.com is mainly showing stations in Europe, but the functionality is similar to previous ones. Reviewing already existing systems authors can conclude that there are several good initiatives for EV users, which ease the EV charging process, but authors did not find any system that is linked with charging station hardware for real-time status and data updates.

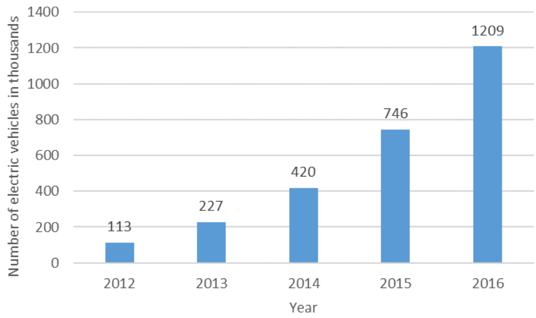

Figure 1: Number of battery electric vehicles in use worldwide from 2012 to 2016.

Authors idea is to provide a platform for successful collaboration between EV users and persons with electro energy availability. Such platform allows EV users to easily plan route and choose charging stations, where to stop and charge a car.

From other hand, such system can allow station owners to efficiently use their station resources. Current development trends of charging stations show shift to renewable energy sources (e.g. photo-voltage panels, wind turbines, geothermal and their combinations). Taking into account fluctuations of available energy and its storage challenge, charging station owners desire to use available energy as efficiently as possible. One of options is to sell free energy to EV users on the open market.

There is a need of a platform to bring together drivers of EVs and owners of the infrastructure to share information about charging points, available amount of energy, capacity and charging price. This will allow convenient charging of EVs almost everywhere. Similar to parking place monitoring and publishing of free parking lots (Zacepins et al., 2017) also number of free charging plugs should be available online, because it is not enough to know charging station location, but also availability and price information of particular station is crucial.

2 ARCHITECTURE OF THE WEB PLATFORM FOR MANAGEMENT OF THE SMART CHARGING STATIONS

Developed platform is built like an interactive map, based on Google Maps service. There are three system user roles: guest, power user and administrator.

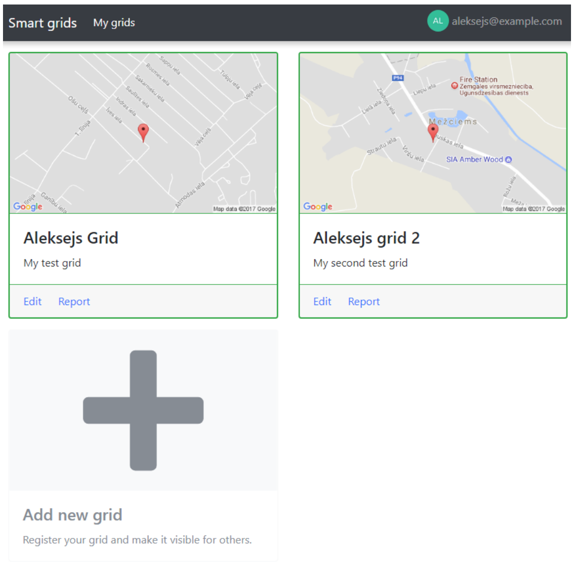

Figure 2: System screenshot of charging stations registered by user.

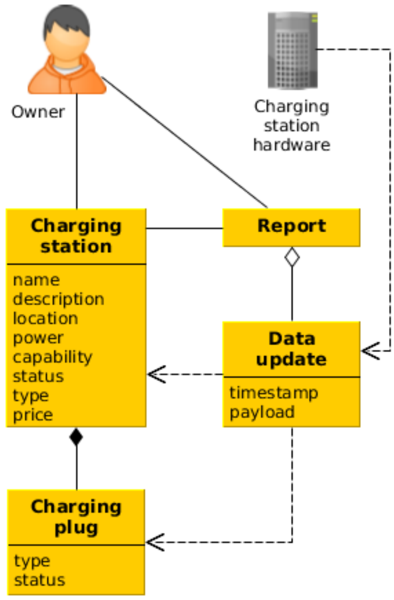

Figure 3: Domain structure.

User registration and management process is maintained using the Auth0 platform (*https://auth0.com/*). For public users (guests) basic information about active charging stations is available, and they have read-only access to the platform. Power users can register EV charging stations: add description and link station hardware to automatically update key information, see Fig.2. In order to register owned charging stations, user has to sign up to application via any e-mail or Google account, administrator accepts sign up and grands needed user rights. After registering the grid it will appear on the public map. In addition power users can edit own charging stations, optionally hide it from public view and review data update reports.

Front-end module is built as single page Web application using Angular 4 and Bootstrap 4 frameworks. Front-end module provides mobile-ready user interface for charging station management and visualization. System shows general information about charging stations, which are added by power users. General information includes description, location, description of charging plugs, availability, charging price, available amount of kWh, reviews of other users, etc.

Back-end module is built using Java technology stack: Spring Boot 2.0 framework as system backbone, MongoDB 3.4 database. Functionality is covered by unit, integration and acceptance tests using Spock 1.1 framework.

System domain structure is shown on figure 3. Charging station *owner* is represented by authenticated user with rights to register new charging stations (power user role). *Charging station* concept in essence is geographical location with name and other relevant attributes, like electrical power, capability, energy source type and charging price. In addition it has status indicator for better management by the owner. Charging station might have several *charging plugs* available for simultaneous charging of multiple EVs. Each plug is described by its type and status (e.g. free, occupied, etc).

Charging station *hardware* is treated as external unmanned party which pushes updates about its state via provided API. Payload of *data updates* is decoded and used for updating information of charging station and its plugs. In addition data updates are aggregated into *report* which provides valuable information for charging station owner about its facilities (e.g. usage patterns).

Web platform for review and testing is publicly available at *https://smart-grids.science.itf.llu.lv/*.

Charging hardware linking to the Web platform is performed via user interface. On the charging station Edit page power user has access to API secret, which is unique code used for sending data updates about particular charging station. User can renew the secret code, when it is necessary.

Below is an example of Python script which might be used to push data updates from Raspberry PI or any other computer to the system. First of all system has to obtain authentication token, similar to user login, but for unmanned system. POST request to Auth0 specified endpoint with *client_id*, *client_secret* and *audience* payload is performed.

```
import requests
payload = {
  'client_id': '<client_id>',
  'client_secret': '<client_secret>',
  'audience': 'smart-grids-web-api',
  'grant_type': 'client_credentials' }
auth = requests.post('https://smart-grids.eu.
    auth0.com/oauth/token', payload).json()
```

It returns dictionary with authentication token, which is valid for 24 hours, so there is no need to run it for every data update, only once a day. For actual data update following script is used. POST request to Web platform end-point is performed. Request headers contain authentication token and request payload contains unique grid API secret key and other relevant values provided by the hardware in JSON format.

```
import requests
payload = {
  'gridKey': '<unique-grid-api-secret>',
  'firstValue': 123.456,
  'secondValue': 'Lorem ipsum',
  'thirdValue': ['list', 'of', 'values'] }
headers = {
  'authorization': auth['token_type'] + ' ' +
    auth['access_token'],
  'content-type': 'application/json' }
requests.post('https://smart-grids.science.itf.
    llu.lv/api/updates', json=payload, headers=
    headers)
```

Successfully saved data updates appears on grid's report page.

Next section describes a working example of such charging station hardware, that can be linked to the Web platform to provide data updates and get inputs for effective operation autonomously.

3 EXAMPLE OF ONE SMART CHARGING STATION LINKING WITH THE PLATFORM

Within this research, one Microgrid (MG), based on renewable energy sources with EV charging station functions is developed and is fully functioning. In general, charging station has three internal energy sources: small wind turbine (emulated), photovoltage array and Li-ion battery storage and connection to the common 230V/50Hz power grid as fourth energy source. The system is capable to choose appropriate source (or multiple sources) depending on foreseen energy inflow and current demand of charging power. Depending on public power grid usage price for charging is fluctuating, which also affects

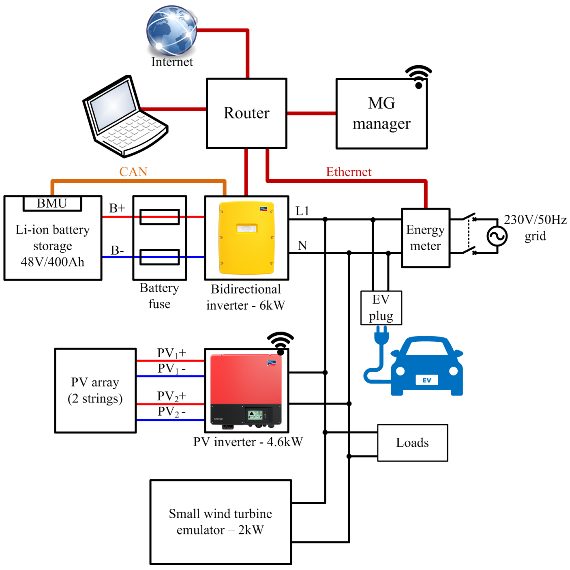

Figure 4: Diagram of the MG charging station for EVs.

source selection strategy. Charging station is located in Brasov, Romania in the Transylvania University. Charging station has 6kW rated power, 16kWh energy capability and single-phase 230V EV socket (Level 1 and Level 2). Schematic diagram of the charging station is demonstrated in Fig.4.

Hardware design and setup peculiarities is out of scope of current paper. The only focusing component of the charging station is network communication interface (full-size or micro computer) witch is connected to the Internet and is capable to send data updates using example Python scripts or similar solutions. On figure 4 it is marked as MG (Microgrid) manager.

Currently charging station operates in "on-demand" mode: energy needs are considered only when there is a charging request. However system could operate in much efficient way by planning and forecasting energy demands for near future. In this, charging station reservations might be an input for energy consumption prediction. This feature is also planned for implementation on the Web platform. That way data flow is organized in bi-directional way: charging station updates current status and parameters on the Web platform in return receiving user reservations for better operational planning.

4 CONCLUSIONS

Within this research Web platform for collaboration between EV drivers and charging station owners is developed. Platform ensures efficient information flow from charging station hardware (real time status updates) and mobile-ready public information site. Web platform uses universal data exchange protocols, which makes hardware linking simple and convenient for end user (owner).

An example case of such charging station linking to the platform is described.

Usage of this Web platform facilitates dissemination of residential charging stations with renewable energy sources, which in turn improves EV driver experience, comfort and availability.

There are several future development directions available. One is directly related to improvements of the Web platform itself: a) development of charging station reservation functionality, b) development of user feedback section, c) extension of reporting functionality to provide useful information both to EV drivers and owners of charging stations. Another direction is to implement multi-grid charging station hardware in urban environment and link it to the described Web platform. Hardware implementation details are out of scope of this research.

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