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Integration in internet of things of electric vehicle charging infrastructure

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Abstract

All across the world, the electrification of road vehicles is growing quickly. With electric vehicle sales shooting up, there is a greater need to develop a robust charging infrastructure. More than just installing charging points, the bigger challenge lies in managing a large fleet of devices dispersed across geographic locations. There are challenges in developing the electric vehicle ecosystem, including infrastructure management, addressing customer experience, profitability, maintenance, monitoring, energy management, and ultimately, how to create a universal ecosystem that works for everyone. Internet of Things technology is a promising player in bringing it all together. In this paper, through a specific case study, is pointed out the importance of IoT integration in the electric vehicle ecosystem, as one of the key management factors. By monitoring the charging network, it is possible to independently manage the power and its distribution and obtain real time reports on charging behavior and data on vehicle models. Internet of Things usage enables charge point operators to remotely monitor and manage operations and quickly resolve issues by presenting real-time insights into usage and device performance, including charger availability, fault monitoring, and troubleshooting – all of which help enormously when it comes to predictive maintenance and reducing downtime. In conclusion are identified the new benefits of Internet of Things integration of the electric vehicle infrastructure.

1. Introduction

The energy and transport sector will face important challenges in the next decade. Decarbonization and pollution reduction are no longer optional, and new technologies and solutions need to be deployed to reach the ambitious targets set by international regulation. Electric mobility represents a crucial opportunity for more sustainable transport, and its optimal charging management could generate relevant benefits for the energy sector too [1].

According to McKinsey, over 40% of the Internet of Thing's economic value will be contributed by operations optimization and account for $1.3 trillion by 2030. With EV sales shooting up, there is a greater need to develop a robust charging infrastructure. More than just installing charging points, the bigger challenge lies in managing a large fleet of devices dispersed across geographic locations. This fact is taken from the paper 'Digital transformation in EV charging value chain' by Dhaval Bhagra, which focuses on the growing needs of IoT in managing real-time operations and helping the EV charging industry grow [2]. Unlike the non-networked gasoline fuel stations, the EV charging stations are connected devices and integrated with various third-party services such as energy suppliers, e-Mobility Service Provider(e-MSPs), and charge point operators [3]. The transition to electric mobility is a promising global strategy for decarbonizing the transport sector by hybrid energy system [4].

They use various protocols & connectivity options and back-end cloud infrastructure to ensure seamless charging operations such as payment processing, software updates, scheduling, predictive maintenance, and usage analytics. Besides all the factors favoring EV adoption, the key to success lies in the development of robust charging infrastructure [5].

The real challenge is not about installing a large number of charging stations, but the ability to remotely manage and smoothly operate dispersed devices. IoT has the potential to resolve the problems of the EV charging industry and enhance the overall adoption of EVs. The paper presents a network of electric chargers integrated in IoT [5-6], for managing the charging network and monitoring power and its distribution. It is also presented dynamic energy management, to utilize the maximum energy potential, where the whole process is achieved through special IOT communication protocols, as illustrated in Figure 1:

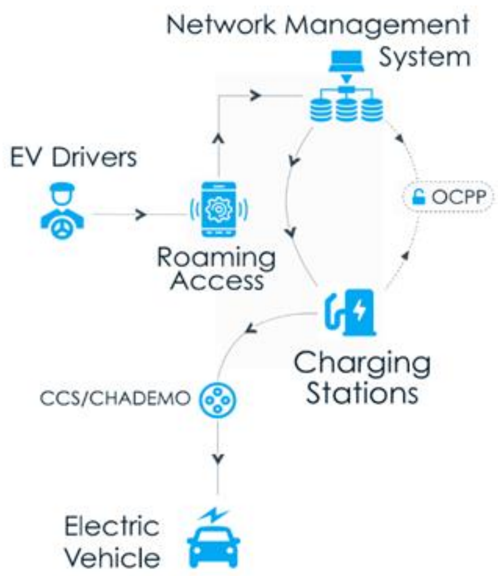

Figure 1. IoT architecture implementation

2. Material and Method

2.1. Electric vehicle charging station

An electric vehicle charging station connects an electric vehicle (EV) to a source of electricity to recharge electric cars, neighborhood electric vehicles and plug-in hybrids as shown in Figure 2 [2]. Some charging stations have advanced features such as smart metering, cellular capability and network connectivity, while others are more basic [3,5]. Charging stations are also called electric vehicle supply equipment (EVSE) and are provided in municipal parking locations by electric utility companies or at retail shopping centers by private companies.

These stations provide special connectors that conform to the variety of electric charging connector standards. There are three categories or types of charging: Trickle Charge, AC Charge and DC Charge. The slowest method of charging your EV at home, using a standard (three-prong) 220V plug [7].

Figure 2. EV station

Different technologies are available for EV charging as shown in Figure 3 [8]. Wired solutions using conductive methods are by far the most diffused as they can easily guarantee the required power level, safety and interoperability with most of the vehicles; non-wired solutions (exploiting the inductivity principles) are being studied for highway applications. Battery swap is for special applications (car races) where rapidity is paramount, and could prove to be suitable for fleets, sharing and/or heavy-duty application. Alternating Current (AC) infrastructures rely on vehicles' on-board chargers and are limited in power level due to vehicle limited size and cost [9-10].

However, Direct Current (DC) infrastructures use off-board power electronics, installed at the charging station. This allows for larger/bulkier and more expensive components, meaning a charging power of up to 350 kW in today's best performing devices. Although in the first years of E-mobility development the trend was to improve AC charging power (up to 43 kW in some models), the present approach is to limit AC charging to less than 22 kW (often 7 kW single phase or 11 kW three-phase). In fact, fast charging will be performed by a DC charger, which is becoming standard equipment for all EVs [11].

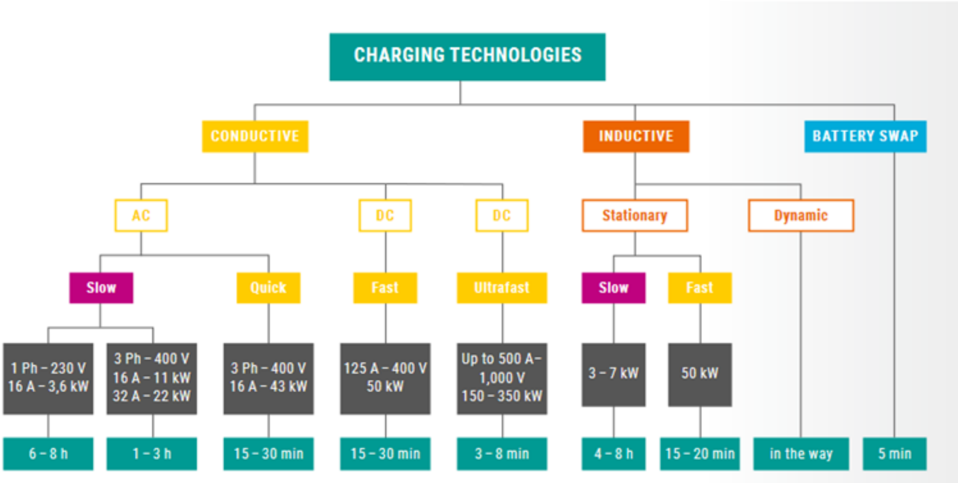

Figure 3. EV Charging technologies

2.2. Integrating electric vehicles in electricity distribution systems

EV charging is the physical interface between these two evolving sectors, emphasizing the dual nature of EVs: a transport means when on the move but a grid-connected battery when parked (and plugged). Related challenges and opportunities are therefore intertwined: on the one hand the proper deployment of charging infrastructures and the optimal management of the charging processes guarantee the required driving range and the optimal charging costs to EV drivers; on the other hand, they transform the stress on the electric grid into the opportunity to provide benefits as a flexibility resource. The possibility to optimize the charging process according to a wider system view, known as "smart charging", must accompany the widespread adoption of EVs. Further benefits can be seized by extending the smart charging concept to vehicle-to-grid (V2G) solutions, where the use of bi-directional chargers permits a deeper degree of integration of planning and operation of both transport and power systems. This is shown in Figure 4 [12].

Figure 4. Integrating electric vehicles in electricity distribution systems

A surging usage of charging infrastructure will create high loads on feeder lines of electricity distribution networks; this needs to be managed carefully to keep the national grid stable. One sensible solution enabled by IoT connectivity is embedded demand management with the purpose of peak shaving.

Charging point operators need to know the available net capacity from energy suppliers at any given point in time, and in return should provide at least 24-hour charging predictions to energy suppliers. This allows automated data-driven operations of both infrastructures [12-13].

Most drivers charge their cars at home, hence, most of the vehicles will be charged in the early evening when the EV driver returns from work. However, when a high number of EVs are charged around the same time, a high amount of power is required from the grid which can lead to congestion problems. This can be compared to a traffic jam: when all drivers return home from work at 6 pm, heavy traffic is likely to occur. When the roads are congested, the driving time increases. Similarly, when too much energy is request - ed from the grid, the power lines do not have enough capacity to deliver this energy. In - stead of higher driving times, congestion at grid level results in loss of power quality and even outages. This can lead to a damage of household appliances, data loss or automatic resets [12].

2.3. IOT integration case study

In simple terms, the IoT can be viewed as a convergence of OT (Operational Technology) and IT (Information Technology) [2,14]. While OT deals with the operations of physical properties such as devices, sensors, and connectivity, IT focuses on the digital transformation aspects. In the view of EV charging, IoT comprises three major elements charging equipment, mobile app, and charging management platform [3].

IoT in EV charging enables continuous monitoring and presenting data in form of reports & dashboards. It also helps in notifying users in the event of critical failures or important updates. Charge point operators can remotely troubleshoot devices without a physical visit. Network operators can enhance roaming services for their charging network as illustrated in Figure 5 [10]:

Figure 5. Diagram of IoT in EV charging

In an era of Big Data, when real-time information and advanced connectivity play significant roles in many industries, IoT becomes a key solution, which allows companies to hold the lead. According to IDC, worldwide spending on IoT-powered technologies, in 2022, will grow to $1.2T, at 13.6% CAGR [15].

As we can see from the numbers above, the world is heading towards higher connectivity. The expansion of "smart devices" on par with digitalization initiatives will undoubtedly influence every aspect of human lives and catalyze business innovations, thus enabling organizations to stay competitive and keep up with global challenges [1,15].

All these challenges are making the Internet of Things, or IoT, increasingly crucial for EV charging. According to McKinsey, nearly 40% of the IoT's economic value will be contributed by operations optimization and account for $1.3trn by 2030. As electric vehicle sales continue to increase, there's a greater need for reliable charging stations [10,15]. Under the context of EV charging, IoT can best be explained as a combination of OT, or Operational Technology, and IT, or Information Technology. By connecting to the internet and becoming wireless, charging stations can offer a range of benefits and capabilities that are otherwise impossible with remote, offline devices.

An IoT system for EV charging comprises three major elements:

- Charging stations
- A mobile app
- And, a charging management platform

The charging network system that is considered in this study consists of KemPower Satellite electric chargers, where each charger has Charging Power Unit (CPU) [7]. Each CPU cabinet provides up to 200 kW of charging power from four power modules into one or up to eight charging plugs on Satellite posts. Charging stations are geographically dispersed, making it challenging and expensive to manage 'onsite'. IoT enables CPOs to remotely monitor and manage operations and quickly resolve issues by presenting real-time insights into usage and device performance, including charger availability, fault monitoring, and troubleshooting – all of which help enormously when it comes to predictive maintenance and reducing downtime.

Additionally, as charging station buildouts increase, data on existing deployments will help operators more accurately plan locations for new stations. Data can also be used to optimize charger utilization, identify areas for improvement, and track trends over time. In the Figure 6, the location of each charger is shown, which is continuously viewed in the system.

Figure 6. Geolocation of the charger

Each Charging Power Unit (CPU) consist of 1-12 power modules, with 2 independent power channels on each module and optional dynamic module that can route the power channels in any order to a maximum of eight charging outputs. To utilize full potential of each DC charger, dynamic power management is one of the key elements on Adaptive EV charging.

Compared to the traditional static charging, Adaptive EV charging can benefit from re- routing the power channels even during each charging session. It enables true flexibility to DC charging and improved OPEX as charging service power levels can also be adjusted to match with real-time energy price level as well as to eliminate possible power peaks in advance.

On the democratic power management shown in Figure 7, each charging output is granted with 25 or 50 kW from the beginning of each charging session, thus on an empty charging area, the first vehicle receives maximum power until next vehicle starts to charge. That starting power level is depending on the number of power modules versus number of charging outputs and their charging cable sizes.

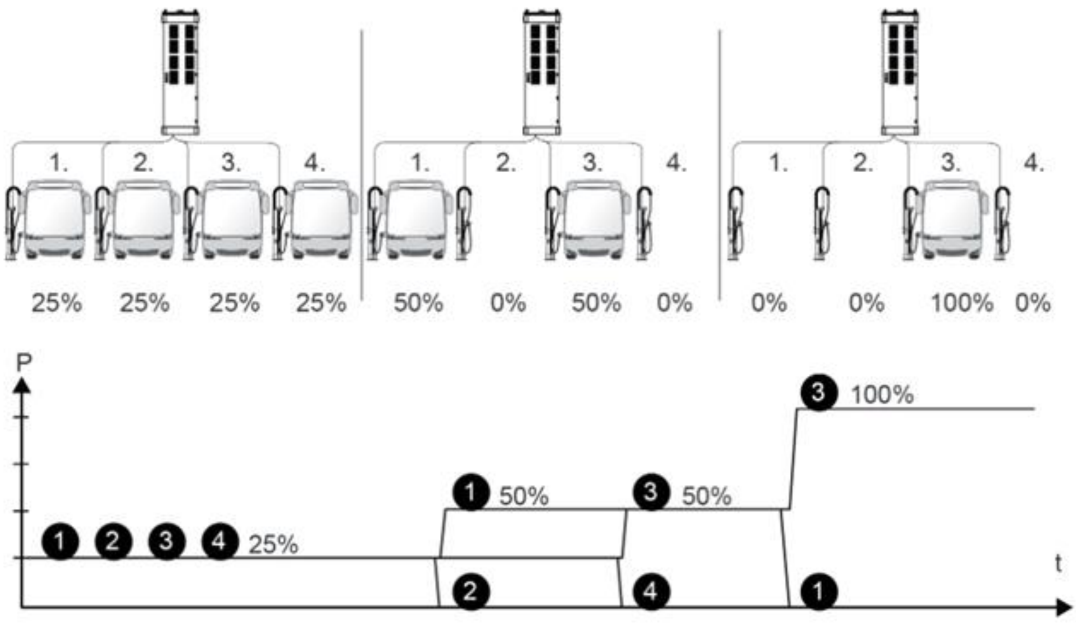

Figure 7. Democratic power management

On a simple case - at the beginning as all EVs are charging on outputs 1-4, each EV receives 25% of the cabinet's charging power. When the EVs on outputs 2 and 4 end charging, remaining charging power 50% is available and is routed to EVs on outputs 1 and 3 (both receives +25%). When the EV on output 1 ends charging the remining power (50%) is routed to the EV at output 3 if it can accept more power, it will receive 100%. Depending on charging application the dynamic power management - routing of charging power works both ways.

Charging power is also reduced when more vehicles are plugged for charging. On such a democratic power management when the CPU has 200 kW maximum power and four outputs, as if the first EV is able to receive the charge at 150 kW power level it starts at that level. As if the next EV also demands 150 kW both EVs receive only 100 kW. And when the third arrives the power is split into three equal parts to 3 x 50 kW where 50 kW is booked to reserve. And when the fourth EV arrives it will receive the remaining 50 kW charging power.

On the arrival priority power management shown in Figure 8, the first arriving EV is granted with maximum charging power from the beginning to the end of its session. Arrival priority power management in turn targets on getting the first vehicle ready as fast as possible to free capacity for the next vehicles arriving and to minimize charging queues. The highest starting power level is depending on the charging points output capacity and maximum charging power level that the EV can accept and on the charging system power capacity.

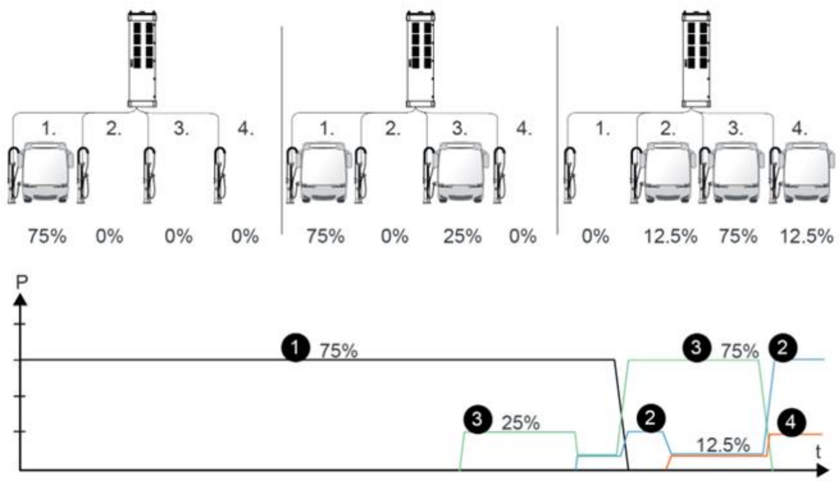

Figure 8. Arrival priority power management

On a simple case shown in Figure 9, at the beginning as the first EV starts to charge at 75% (150 kW), when the next EV starts to charge at output 3 it receives 25% (50 kW). As the third driver starts to charge on output 2 the first arrived still receives 75% and second and third receive only 12.5% (25 kW each). By the time the first EV ends its charging session, that power is first routed to output 3 and remaining 25% (50 kW) to output 2. When the fourth EV starts to charge, charging power is divided to half to two single channels (25 kW) for both 2 and 4 outputs. And as the EV on output 3 ends its session that power is routed to EV on outputs 2 (75%) and 4 (25%).

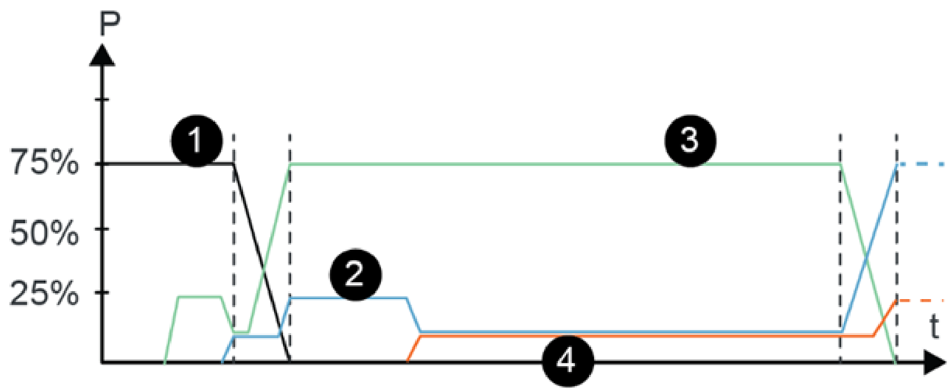

Figure 9. Power at the charging station outputs

In both power management cases, democratic and arrival priority, when there is free power for charging available the CPU communicates with each vehicle and offers additional power. During that communication, each EVs BMS confirms if additional power level is acceptable. After that asynchronous conversation, a selected number of power channels are re-routed to specific EVs.

3. Results and Discussion

In the case studied in this paper, through the charging system, real-time data of electric chargers were obtained. The data obtained are the power received by each electric car, the charging time, the specifications of the cars that have been charged, the work cycles of each connector of the electric charger, the work cycles, the time without providing energy.

All these data serve the operator to manage the power through each charging session, and to analyze the operation of each charger in different locations. Also, by receiving data in real time, it helps in the management of the integration of charging systems in the infrastructure of the energy network in the country.

Through intelligent measurements in the field at the charging stations, the energy needs of each car are monitored. Through dynamic energy management, the adjustment of the power levels of the charging service is realized in accordance with the level of the energy price in real time. Since the maximum power of the charging power unit for the used charger is 50 kW, it can be seen from the graphs that the machines were charged with maximum power, and then the power decreased according to the need they had. Figure 10 shows the appearance of the system on the monitor:

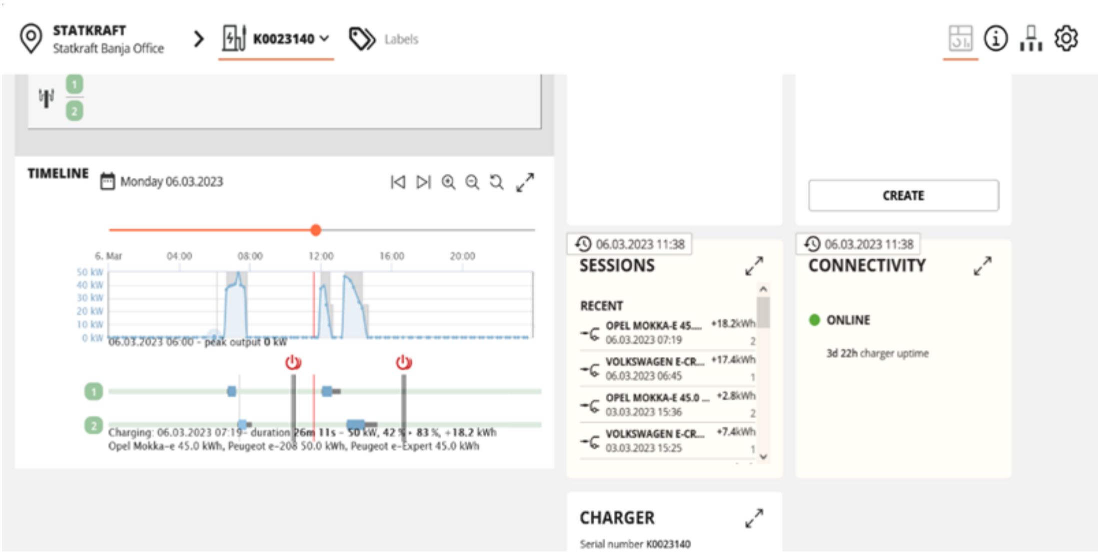

Figure 10. EV charger system dashboard

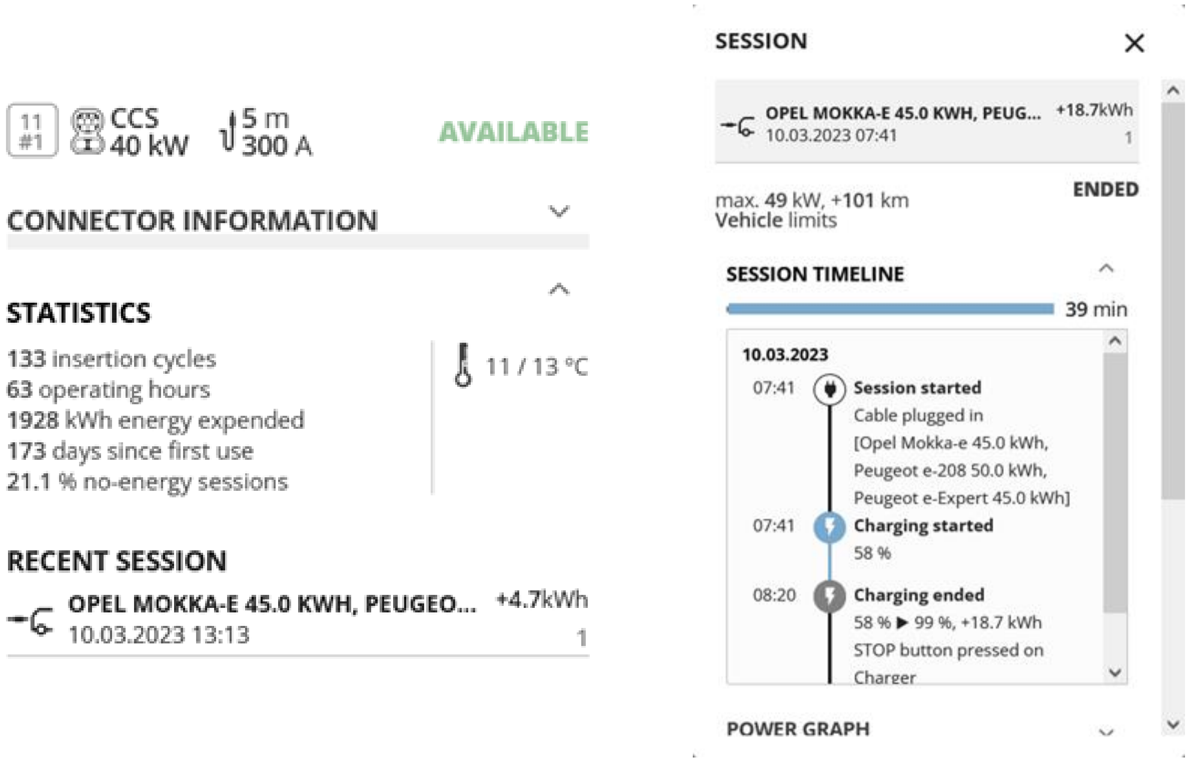

Figure 11. Data from the charging station

By managing the data for each charger at the charging station, the statistics of their operation are obtained shown in Figure 11.

In the reviewed period, the charging data of the car OPEL MOKKA-E, PEGGEO were obtained, where we receive information on the cycles of introduction to work, which are 133, hours of operation 63 hours, energy spent 1928 ckkWh, 173 days in operation since the first day and 21.1% sections without energy. It is noted that the charger operates at temperatures of 11/13 degrees Celsius. Also, the operator received information that the car has a power value of 58%, and is charged with 49 kW, which translates to 101 km, which are also the limits of the car. The car is charged with energy +18.7 kWh, in a period of 39 minutes.

Charging stations are geographically dispersed, making it challenging and expensive to manage 'onsite'. IoT enables CPOs to remotely monitor and manage operations and quickly resolve issues by presenting real-time insights into usage and device performance, including charger availability, fault monitoring, and troubleshooting, all of which help enormously when it comes to predictive maintenance and reducing downtime. Figures 12 and 13 show the location of the charging station under consideration, through which real-time data is obtained virtually.

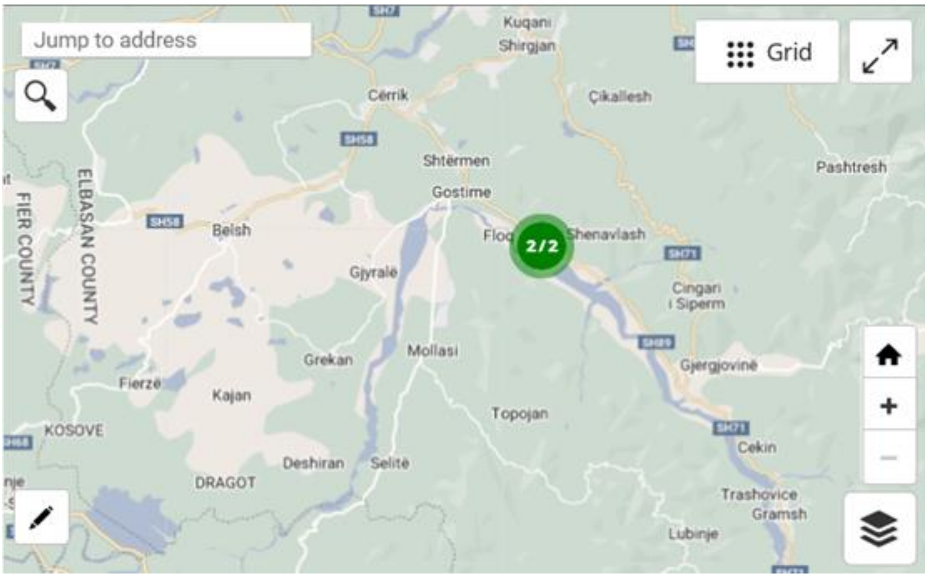

Figure 12. Satellite view of the charging station

Figure 13. Location of the charging station taken in the study

Through this use case, EV drivers can quickly ascertain where the nearest charging station is, what their state of charge (SOC) is and charging rates and payment options for smart charging. They'll also be able to schedule their charging at the most convenient and economical times of day, initiate the charging and authorize payment via credit/debit cards or other payment arrangements all from a smartphone app. One convenient payment method that CSPs can offer to their EV smart charging partners as part of their managed, integrated 5G platform services is the wallet payment service. Figure 14 shows the data acquisition of each log in the charging station.

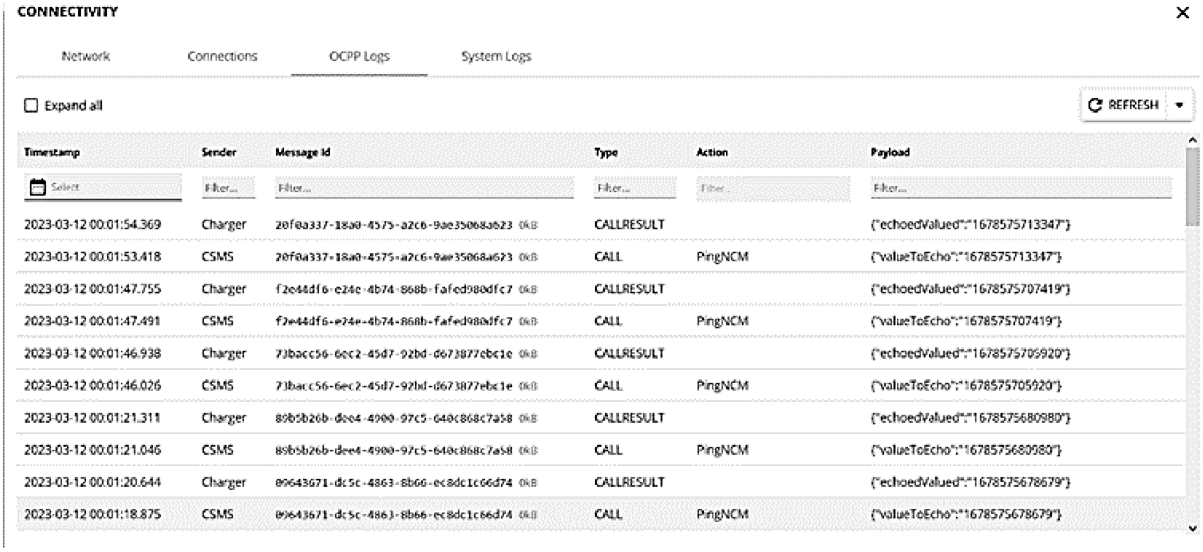

Figure 14. Data acquisition of each log in the charging station

4. Conclusion

Although significant advancements have happened in EV charging technologies (such as DC rapid charger that can fully charge an EV within 90-120 minutes), a robust technology backbone should be developed to manage and scale a charging network without geographic boundaries.

More than just remote monitoring, IoT is a fundamental block for developing next-gen applications such as smart charging and vehicle-to-grid. Not only for EV drivers, but IoT is also equally important and beneficial for everyone as it helps CPOs to prevent downtime, grid suppliers with energy management, and create a large roaming network for a seamless charging experience.

The case study of IoT integration of the KemPower chargers' network is presented and real-time data is obtained and analyzed. The main identified benefits are:

- Improved Authentication. Before charging the EV, the users need to verify themselves with the help of smartphones or RFID tags for access. This high-end authentication ensures secure billing and transaction.
- EV Station Search. Finding an EV charging station in an unfamiliar area is hectic. With IoT, EV owners can easily find nearby stations by searching the application's location, checking availability, and reserving a slot in advance per the charging requirements.
- Smart Charging. With the help of IoT, the chargers can find the lowest rates available from the grid and start charging automatically. This facilitates the CPOs to manage the surge in energy demand and save costs.
- Remote Operation Management. IoT solutions have enabled the CPOs to take real-time device performance insight into account and quickly resolve the associated issues while remotely managing the other EV station operations.

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Author contributions

Miranda Harizaj: Conceptualization, Methodology, Investigation, Writing-Reviewing and Editing. **Igli Bisha:** Writing- original draft preparation, operation and testing.

Conflicts of interest

The authors declare no conflicts of interest.

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