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An overview of the future smart charging infrastructure for electric vehicles

Tole Sutikno
Master Program of Electrical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
Embedded Systems and Power Electronics Research Group, Yogyakarta, Indonesia

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ABSTRACT

Smart charging is a technology that allows electric vehicles (EVs) to communicate with charging devices. This paper presents an overview of smart EV charging. Smart charging is a future solution for businesses, allowing them to remotely monitor EV charging events, manage charging stations, and concentrate on their core operations. It also simplifies payments, regulates electricity consumption, and makes charging stations easy to manage. Smart charging solutions assist utility companies in developing their own EV charging networks by stabilizing the grid, adapting to changing demands, and easily managing multiple charging stations. Furthermore, the visibility of all actions at charging stations facilitates keeping track of business activities. Smart charging is a critical component of electric vehicles (EVs) because it provides future-proof features such as cloud connectivity, standardized socket types, and backend compatibility. Smart EV charging includes an admin panel for managing multiple charging points, automatic payments and billing, end-user mobile and web apps, charging station roaming, dynamic load management (DLM), and energy management. These features enable charging stations to better manage their resources, attract more users, and protect the local grid against peak loads.

Corresponding Author:

Tole Sutikno
Master Program of Electrical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan
Ahmad Yani Street (South of Ring Road), Tamanan, Yogyakarta 55166, Indonesia
Email: tole@te.uad.ac.id

1. INTRODUCTION

Smart charging is a revolutionary technology that regulates the timing and manner in which an electric vehicle (EV) is supplied with power for charging [1]–[13]. It considers factors like electricity costs, availability, and driver requirements. This technology allows operators to oversee, control, and modify energy usage. A data connection is necessary between the EV and the smart charger, as well as between the charger, the cloud-based EV charging management platform, and the grid. Cloud-based solutions [11] allow for easy modification of the charging service, adding or removing features to suit individual needs. This future system supports electric cars connected to the grid, creating a symbiosis with the power grid, preventing the burden of electric vehicles on the grid [5], [8], [10].

The process of charging an electric vehicle through smart charging involves the insertion of a charging cable by the owner, which initiates a communication session between the smart charger and the vehicle. Once the driver and vehicle have been duly registered with the EV charging provider, no further actions are required. The intelligent EV charging platform identifies the driver, starts the charging session with the most efficient energy usage, tracks the battery level in the vehicle, ends the session when the vehicle is fully charged, and invoices the driver according to their mutually agreed-upon conditions [1]–[7], [11].

Simultaneously, a communication session is initiated among the charger, the remaining chargers, the energy resources present at the charging location (referred to as the infrastructure), the grid, and the charging operator's intelligent electric vehicle charging and energy management platform. This software platform, which is centralized and cloud-based, oversees the chargers, the charging session, and the energy sources utilized [12].

Smart charging is a secure and expedient method of recharging an EV during periods of reduced electricity demand, such as during nighttime or when there is an abundance of renewable energy sources available on the power grid [5], [8], [10]. Charging during off-peak periods not only yields cost savings for EV drivers through the utilization of more affordable energy rates, but also serves as a preventive measure against unanticipated periods of excessive electricity demand from the grid [3]. This paper will provide an overview of smart EV charging, including how smart EV charging stations work, the benefits of smart charging systems, and the elements of smart charging.

2. SMART EV CHARGING STATION

Smart charging is a convenient way to charge electric vehicles (EVs) at home without costing a fortune. Smart charging stations typically charge vehicles at times when the demand for electricity is lower, helping homes save money and reducing the demand for electricity from the National Grid. Users send charging preferences to the smart charger, which a network like 3G/4G/5G, ethernet, or Wi-Fi then sends to a centralized cloud-based management platform. Internet of things (IoT) SIM cards play a crucial role in keeping smart electric car charging stations connected [1]–[7], [11].

IoT connectivity can help users track their charging habits and schedule, optimize their charging schedule, and monitor their car's charging status even when they're inside or away from home. There are different types of connectivity that smart EV chargers can use: IoT SIM cards, ethernet, and Wi-Fi [11]–[13]. SIM card connectivity is an important and increasingly common type of connectivity for smart EV chargers, as it is generally inexpensive and allows for remote monitoring. Ethernet connectivity is another option for smart EV chargers, but it can be more difficult to install than IoT mobile SIM cards, particularly in private properties with fewer complimentary groundworks needed. Wi-Fi connectivity is another option for smart EV chargers, but it can be difficult to provide constant service and can be unreliable when monitored for mission-critical real-time applications. IoT devices work best when set up and fitted to work seamlessly by expert technicians or installers, signed off, and managed via integrated central systems or user apps [4].

Smart charging requires an electric car driver to identify at the charging station. Identification connects the EV driver, charging point, and the charging event together. The right price will be charged from the right customer, and money will be directed to the correct charging station owner. And because it’s smart, everything happens automatically. Identification is effortless for EV drivers registered to the charging service: they just log in to the mobile application and start charging or show their RFID tag to the charger [2]–[7], [11]–[13]. Unregistered users can also use the stations and pay with a credit or debit card. The charging event itself happens based on the settings and prices the station owner sets. The station can be part of a station group and include many smart features occurring in the background, but for the end-user, charging an electric car is as easy as it can be: they simply identify and plug in. The number of smart EV charging service providers is increasing, and all these service providers have their own charging platforms. This causes no trouble for EV drivers when cars are charged smartly, thanks to roaming networks. Most smart charging platforms, like ours, are connected to roaming platforms. Through roaming, customers can charge at any station with just one customer account [3]–[6], [10], [11], [14], [15].

An efficient charging management system for electric vehicles relies on effective communication among electric vehicles (EVs), electric vehicle supply equipment (EVSEs), and the power grid, as illustrated in Figure 1. We categorize different communication protocols based on whether they operate through wired or wireless technologies. Various types of private networks, including home area networks (HAN), industrial area networks (IAN), building area networks (BAN), neighborhood area networks (NAN), or field area networks (FAN), have the capability to incorporate the utilization of electric vehicles (EVs). These networks manage the regulation and supervision of the charging and discharging of electric vehicles, as well as other household electricity consumption [16]–[18].

2.1. Wireline communication for smart EV charging station

Wireline technologies are well-suited for long-distance data transfers in major urban areas, making EV charging stations an excellent choice. Power line communication (PLC) is a widely used data communication protocol in wireline technology. This technology utilizes the identical power line for both transmitting and receiving data. Its robustness and reliability enable it to withstand interference. Various protocols, including Home Plug 1.0, Home Plug Turbo, Home Plug AV, High Definition - Power Line

Communication (HD-PLC), and Universal Powerline Alliance (UPA), employ the concept of PLC. In wireline communication, we additionally incorporate optical and digital subscriber line (DSL) protocols. Optical communications offer a notable advantage in terms of their substantially higher data rates (reaching several Gbps) and transmission ranges (extending to several kilometers) when compared to PLC. Optical communication is highly resistant to electromagnetic interference. This technology facilitates the transfer of data across a high-voltage power line [19]–[35]. The DSL protocol enables digital communication over a telephone line, eliminating the need for separate infrastructure [16], [36], [37].

2.2. Wireless communication for smart EV charging station

Wireless communication is essential for enabling the transfer of data between vehicles and charging stations, thereby establishing a complete communication framework. Electric vehicles utilize this feature to convey information regarding their charging status. Wireless communication networks utilize hierarchical mesh structures to interconnect electrical devices. Wireless LAN devices consist of a hierarchical mesh structure. The process of connecting an electric vehicle (EV) grid involves the utilization of four widely-used wireless technologies: Zigbee, cellular, WI-FI, and satellite networks [16].

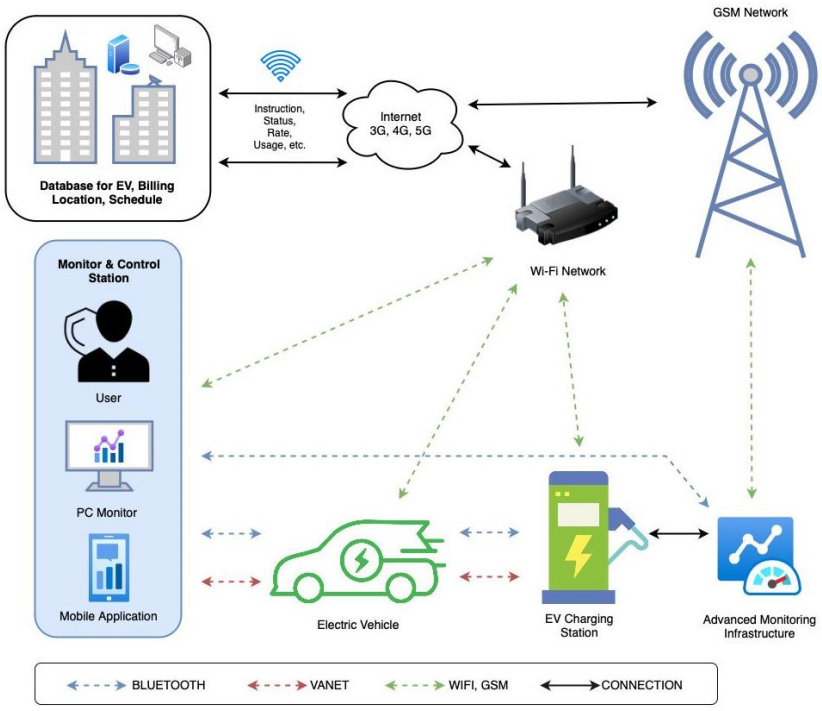

Figure 1. The future smart charging infrastructure

3. THE BENEFITS OF SMART EV CHARGING

The energy sector stands to gain a great deal from the implementation of intelligent charging systems for electric vehicles. On the other hand, there are quite a few positive outcomes: drivers of electric cars, owners of charging stations, and managers of charging networks all stand to benefit from greater intelligence. An intelligent system for charging electric vehicles can be beneficial to electric vehicle drivers, businesses, and charging networks in the following ways [8], [11]–[13].

3.1. Benefits to EV drivers

When it comes to charging our vehicle, it does not matter where we do it as long as it stays charged. The following is a list of the primary advantages that electric vehicle drivers can get from using smart charging [8], [11]–[13].

- Find available EV charging stations: Using a mobile app, users can quickly locate public charging stations that are available and reserve a charging location while they are on the move. In addition to displaying information about the charging speed and price, the mobile application also provides real-time data regarding the availability of electric vehicle smart chargers.

- Access fast charger: Automatically, the smart device will consume the maximum quantity of energy that is provided. 22 kW is the maximum charge level that can be achieved by the majority of smart gadgets. Fast charging stations are able to charge even with a maximum power of 150 kW, which reduces the amount of time it takes for vehicles to charge if they have charging connectors and battery capacity that are compatible with the stations.
- Charge safer: A smart charging device is a lot safer and more carefree solution than a standard household outlet, especially when they are compared to one another. Before beginning the charging process, smart gadgets will do a connection test to ensure that they are able to successfully connect to our vehicle. Every charging event is being observed, and it is possible to exercise control over it remotely.
- Avoid arguments with neighbors: Even though charging electric vehicles at home can be liberating for drivers of electric vehicles, it can also be a source of strain if the chargers do not provide appropriate traceability. Because the data on energy usage can be easily tracked back to the appropriate individual, smart charging makes it possible to prevent unnecessary discussions and disputes between neighbors regarding energy consumption. Using smart car charging, all electric vehicle drivers are invoiced depending on the station's tariff when the charging process is complete. We, as an electric vehicle driver, and everyone else who owns a charging point do not need to be concerned about payments because everything happens automatically. Identification of the consumer is the foundation of automated billing; hence, the charging event does not begin until we have successfully identified ourself at the station using the mobile app, RFID tags, or the one-time payment service.
- Save money and the environment: By automatically optimizing the schedule of our charging event to favor charging during times when electricity is at its lowest cost, we will not only save money but also help the environment. It is not only more cost-effective to schedule the charging event to take place during the hours of low electricity usage, but it also contributes to the maintenance of a distributed power infrastructure. The number of driving electric vehicles (EVs) is increasing, and there will soon be a demand for additional flexibility. It is even possible for energy companies to provide incentives to electric vehicle drivers for charging their vehicles with less power, scheduling their charging events during period of low consumption, or allowing their car batteries to be used as power reserves for a short period of time.

3.2. Benefits of EV charging to businesses

Smart electric vehicle charging has a lot of benefits for businesses as well, just like it does for consumers. In point of fact, the only option that is both sensible and potential for the future is to do it the smart way. Smart charging gives us the ability to [8], [11]–[13]:

- Remotely monitor EV charging events: In addition to being able to check usage statistics and report problems, we will have access to a smart management system that will allow us to remotely monitor and regulate charging events. Every single one of our stations is linked to the charging platform, and thus, they are all connected to one another. We are able to organize stations into groups and manage them in a stack. For example, this makes it possible to restrict the amount of power that a station group can charge each individual device. Another helpful feature is the ability to alter pricing bundles and information about charging stations.
- Stop stressing about payments: It would be a straightforward invoicing arrangement. We are not obligated to take any action in terms of bill payment or receipt. We will give us a monthly transfer of the income produced by electric vehicle drivers, who are automatically billed at the prices we specify.
- Control our electricity consumption: In addition, we will be able to take advantage of controlled charging events, which will eliminate the need for us to be concerned about surpassing the capacity of our local grid or paying an exorbitant amount for our monthly electricity expenditures. When stations are grouped together, it is possible to save money because there is no longer a requirement to expand the area of the electrical connection. In the event that the maximum charging power that has been reserved for the station group is surpassed, the charging power will automatically decrease at each and every station that is part of the group.
- Find peace of mind: On the other hand, the most significant advantage of a smart electric car charging system is fairly straightforward: it enables us to maintain our concentration on our primary profession. It is not necessary for us to pay attention to the charging station once it has been placed, unless we are interested in keeping track of the statistics and various commercial information.

3.3. Benefits to EV charging networks

It is an urgent necessity for utility companies that are establishing their own electric vehicle charging networks to have a smart charging solution for electric vehicles. When all is said and done, I don't see how we could possibly serve several charging stations over our own network. Smart charging enables electric vehicle charging networks to [8], [11]–[13]:

- Stabilize the grid: It is possible to control smart charging events depending on a variety of indications; for instance, charging can be automatically configured to begin when the demand for electricity is at its lowest. We will have access to new business options if we have the capability to control charging based on various indications indicating energy production and consumption. Energy management features should be made available to drivers of electric vehicles so that they have the opportunity to voluntarily participate in demand response functions. Other things that consumers require are knowledge and incentives.
- Keep up with the changing world: As a result of the rapid pace of change in the mobility sector, it is not possible to anticipate all of the future requirements. Updating, modifying, and developing smart charging services in the cloud can be done while the user is on the move. Investing in a smart charging solution is equivalent to investing in a service that is up to date.
- Easily manage a number of smart EV charging stations: Creating device groupings, pricing models, and packages for end consumers is something that we are able to do as a network operator. The testing of various prices and the management of station groups are both without difficulty. If we want to get the most out of the intelligent system, we will assist us in using the management tools.
- Stay up to date on our business: The process of keeping up with our business is now easier than it has ever been: All of the activities that take place at our charging stations are mirrored in the management system, and they are compiled into overviews that are both convenient and simple to read. Additionally, we are able to see individual station occurrences and keep track of the most important metrics and statistics.

4. SMART EV CHARGING ELEMENTS

Smart EV charging is a cutting-edge method of providing a superior user experience that allows drivers and charging station operators to have greater command over the charging process. Smart charging is a comprehensive concept that integrates various advanced technologies to enhance the efficiency, optimization, and cost-effectiveness of electric vehicle (EV) charging. The system is a sophisticated network that links various devices, such as electric vehicles, chargers, charging points, and grids, to a cloud-based platform for the purpose of transmitting up-to-the-minute data. Using this data, users have the ability to remotely monitor, control, and fine-tune various aspects of energy consumption.

4.1. Smart EV charging point devices

Despite the fact that all electric vehicles are compatible with smart charging devices, not all charging devices are smart. The term "smart" has been prevalent in recent times. On the other hand, in order to be completely applicable to all of the future-proof feature possibilities that smart charging offers, a smart gadget needs to possess certain features. At a minimum, take into consideration the following three aspects while choosing a charging device [8], [11]–[13]:

- Ascertain that the stations are capable of connecting to the cloud. In order for devices to communicate with the service, they should have a connection that is capable of GPRS or 3G, for example.
- Standardized socket types, such as Type 2 or CHAdeMO and CCS Combo in the case of a fast charging device, should be included in the specifications of the devices.
- It is important that the devices we use are compatible with the backend that we select. The most widely used standard protocol is known as OCPP, which stands for open charge point protocol. This protocol enables users to construct a comprehensive charging experience by combining a variety of software and hardware components.

It is preferable to have a standard version that is more recent; nonetheless, the most essential aspect is that the device and platform that is selected adhere to the same specification. A majority of smart charging platforms will not force us into a vendor trap, which is a fantastic thing to hear.

4.2. Smart EV charging features

The smart features of the electric vehicle charging platform are the true stars of the story, despite the fact that smart gadgets are a necessary prerequisite for smart electric vehicle charging [8], [11]–[13].

- Advanced and optimized charging schedule: Charging an electric vehicle during periods of high electricity rates or excessive demand not only strains the power grid but also results in exorbitant electricity expenses for drivers. Smart electric vehicle (EV) charging allows users to obtain essential information, such as low-cost and peak demand hours. Electric vehicle (EV) owners can utilize this data to ascertain the optimal and economically efficient period to charge their vehicles.
- Remote monitoring and management: In order to have improved oversight, an electric vehicle driver or charging station operator must have the capability to monitor the charging procedure from a distant location. A cloud-based intelligent monitoring system allows charging station operators to access essential data, enabling them to oversee potential issues. Remote monitoring allows them to detect issues and promptly troubleshoot them, thereby preventing any shutdowns.

- Data analytics: The distinguishing factor of smart EV charging, as opposed to traditional charging, lies in its capability to gather, retain, and examine crucial data regarding charging activity. Intelligent charging systems equipped with sophisticated algorithms can detect patterns and forecast the most efficient time and method to charge an electric vehicle (EV). This improves the efficiency of the charging process and the electric vehicle charging infrastructure.
- The admin panel: When it comes to managing several charging points in a variety of places, the admin panel is our best friend. Here, we are able to determine the cost of public charging stations, remotely operate our stations, and examine and download statistics regarding their utilization. We are able to become familiar with our station data and make adjustments to the features, station characteristics, and prices depending on key metrics with the assistance of the administrative panel thanks to the tools that are provided to us. We are able to control the information regarding our clients, registrations, and RFID tag shipments through the administrative panel because we are the operator of the charging network. To put it succinctly, it gives us the opportunity to participate actively in the management of the station; nevertheless, in actuality, everything functions without our engagement. All of the tasks that take place behind the scenes will be handled by us so that we can continue to concentrate on our primary business.
- Automatic payments and billing: By making an investment in smart charging, we will be able to take advantage of other convenient features such as automatic payments and billing. We do not have to manually charge our clients or staff following their charging events because the platform takes care of everything for us. And what is the most exciting part? It is up to our clients to decide how they would want to make their payment. From radio frequency identification (RFID) tags to mobile applications and one-time payments made with a credit card, all that is required of us is to take a seat and relax as the money comes in.
- Mobile and web apps for the end-users: Providing our end-users with mobile and online applications elevates the quality of our customer experience to a whole new level. In addition to allowing drivers to locate and reserve available charge points, they also enable drivers to add their preferred stations, see their charging history, and perform more functions. Real-time information regarding charging stations is displayed to electric vehicle users by the mobile application, which is a smart application. The mobile application provides electric vehicle owners with everything they require for charging.
- Secure plug and charge: Data security is of utmost importance during the charging process. To ensure the security of transactions, vehicle and owner details, billing, and payment information, it is imperative to safeguard against data breaches and malicious third parties. The plug-and-charge feature of smart charging infrastructure employs a range of cryptographic tools to guarantee secure communication between electric vehicles (EVs) and charging stations.
- Roaming: When charging stations are roaming, they are able to attract more customers, which in turn helps them increase their revenue. Roaming enables electric vehicle drivers to charge their vehicles at tens of thousands of stations using a variety of methods, including various programs and cards developed by third parties. In the same way as mobile data roaming does, roaming brings about an improvement in the user experience. Due to the fact that the devices must be connected to roaming networks, smartness is a prerequisite for roaming.
- Dynamic load management: When it comes to smart electric vehicle charging, dynamic load management, also known as DLM, is such an important idea that it is frequently thought of as a synonym for all smart features. Furthermore, dynamic load management is a term that describes the capability of a smart charging platform to intelligently distribute the available power between the building and the electric vehicles that are being charged at the same time. We are spared the trouble of upgrading the building's energy infrastructure thanks to DLM, which, in other words, helps us safeguard the local grid from peak loads.
- Energy management features: In order to connect electric vehicles to the grid, energy management features are the most important components. Electric vehicles are unable to contribute to the infrastructure of the electrical system if there are no smart charging stations available.
- Smart charging app: The EV charging app has become crucial in providing an unparalleled user experience. The intelligent charging application simplifies the process of choosing a preferred payment method or locating accessible chargers. In addition, charging applications enable users to customize the settings and parameters in order to enhance the sustainability of the electric vehicle charging process. In addition, intelligent charging applications consolidate current and past data into a centralized platform. This feature allows the user to examine energy usage and expenses in order to plan and organize their charging procedure.

5. CONCLUSION

A smart EV charging system lets an electric vehicle and a charging device share information. For smart charging to work, drivers of electric vehicles must be able to prove who they are at the charging station. This will make sure that the right person pays the right amount of money and that the money goes to the right owner of the charging station. This paper has given an outline of smart EV charging. The admin panel is a smart feature that many EV charging platforms have. It lets charging network operators see statistics about how stations are being used, manage stations from afar, and set prices. One more useful feature is that charging stations can automatically bill and pay employees or customers after a charging event. Mobile and web apps let users get real-time information about charging stations, and roaming lets charging stations get more users and make more money. Dynamic load management (DLM) is what makes smart charging for electric vehicles possible. DLM lets power be shared between electric vehicles and buildings at the same time. Because smart charging stations are needed for electric cars to work, connecting them to the grid needs energy management features. Smart charging systems are good for everyone, from people who trade in energy to drivers to owners of charging stations to people who run charging networks.

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BIOGRAPHY OF AUTHOR

Tole Sutikno is a lecturer and the head of the Master Program of Electrical Engineering at the Faculty of Industrial Technology at Universitas Ahmad Dahlan (UAD) in Yogyakarta, Indonesia. He received his Bachelor of Engineering from Universitas Diponegoro in 1999, Master of Engineering from Universitas Gadjah Mada in 2004, and Doctor of Philosophy in Electrical Engineering from Universiti Teknologi Malaysia in 2016. All three degrees are in electrical engineering. He has been a Professor at UAD in Yogyakarta, Indonesia, since July 2023, following his tenure as an Associate Professor in June 2008. He is the current Editor-in-Chief of TELKOMNIKA and Head of the Embedded Systems and Power Electronics Research Group (ESPERG). He is one of the top 2% of researchers worldwide, according to Stanford University and Elsevier BV's list of the most influential scientists from 2021 to the present. His research interests cover digital design, industrial applications, industrial electronics, industrial informatics, power electronics, motor drives, renewable energy, FPGA applications, embedded systems, artificial intelligence, intelligent control, digital libraries, and information technology. He can be contacted at email: tole@te.uad.ac.id.