Case study: Electric Vehicle Charging on the smart grid

1. SCENARIO OVERVIEW

This case study covers the convergence of the smart grid and electric vehicle charging. Specifically, this focuses on the security of electric vehicle charging stations (EVCS) as the associated infrastructure. From 2022, in the UK all new build homes must be built with an EVCS provided [1].

The scenario considers a proposed component of the smart grid which allows for distributed power generation and storage, in a similar manner to the current approach taken for home solar generation, wherein excess energy supply generated by home solar panels can be returned to the national grid. The proposals extend this to utilising the batteries within electric vehicles as mobile energy storage units, from which unused power can be returned to the grid as required. Consider the example of a large airport car park in which the majority of spaces are reserved for EV parking and provide charging infrastructure. A car that is parked for two weeks whilst its owners are away only needs to be fully charged at the time the owners return. If the car is charged on arrival, for the two weeks it is sat in the garage it is storing energy that can be used by the grid to meet wider demand. In this case, the charging station can discharge energy from the car and return to the grid, effectively turning car parks into large battery arrays. A similar approach can also be used for home charging, using statistics on owners' behavior to charge cars when needed and to return power when not needed. When charging a car at home, the user is not charged for the power they use, however when charging at another person's home, a car park at work, or when using a public car park, the owner of the charger can choose to charge the electricity use to the owner of the car. This is done automatically, as the EVCS is able to communicate with the car while charging, transmitting the VIN over the charging cable.

We assume three key organisations in the scenario. The first is the charging provider, who manufactures the EVCS used both in home and commercial settings. In home and business owned car parks, they act as a supplier only and do not collect charges; however, they facilitate this for the owners. The provider also operates their own car parks where they directly bill users for energy used. The charging provider provides a smartphone application which allows a car owner to monitor the charging state of their vehicle, and remotely start/stop charging at any EVCS that their car is connected to. They can also use this to locate public EVCS available. The provider is also able to enable and disable chargers as they require. To support these applications, as well as more general monitoring of the charging network, the provider maintains a server infrastructure in the cloud. The charging provider uses electricity from the national grid in their car parks, and purchase energy from an energy provider.

The second organisation is the energy provider. The energy provider is responsible for the energy supply to home users and car parks. Examples of these include EDF, E-ON, Scottish Power, British Gas etc. They are responsible

[1] https://pod-point.com/guides/business/ev-charging-legislation-new-build-uk

for billing the energy supply to users, delivered over the national grid. Their primary goal is to bill customers for energy usage. They do this using smart meters installed into homes and car parks which measure energy usage. If a customer returns energy to the grid through solar or car power, their charges are reduced. To support this, the energy provider maintains server infrastructure for usage monitoring, customer management, and billing. If a customer does not pay, the provider can remotely disconnect the power from the smart meter.

The final organisation is the grid operator, responsible for maintaining power networks, including local substations. Their primary goal is to ensure the continued operation of the electrical grid. The grid operator receives information from the energy provider, and charging provider, about current energy demands.

As part of this case study, you will need to explore the literature on the security of smart grids and electric vehicle charging. You may need to go outside of the academic literature for this.

2. SYSTEM DETAILS

A. Home Charging

Figure S1 gives an overview of a typical home electric vehicle charging scenario. The home can receive power both from the electrical grid, and through a roof mounted solar panel. The electrical systems within the house are managed by a distribution panel, which can switch between solar and grid power supplies for the EVCS as well as the other home appliances. The distribution panel can also provide power back to the electrical grid from either the solar panel, or the vehicle battery, when there is surplus supply in the house. A smart meter sits on the connection to the electrical grid, which is responsible for both measuring the electrical usage from the grid, as well as the amount of energy supplied back to the grid from the house. the smart meter can communicate directly with the EVCS in order to measure currently available capacity.

Note that, for the purposes of this work, we are not considering the home appliances other than the EVCS, solar panels, distribution panel and smart meter.

The smart meter contains a 3G/4G radio for sending and receiving data to the infrastructure of the energy provider, including meter readings. The smart meter contains a remotely controllable relay which allows the energy provider to disconnect the power supply to the home in the case of debt.

The EVCS also maintains a 3G/4G mobile connection to the infrastructure of the charging provider, in order to facilitate the use of a smartphone application which can be used to monitor the charging state of a vehicle and remotely start/stop charging. The cable connecting the car to the EVCS uses the CAN protocol to exchange charging information (battery state etc) between the EVCS and the car.

B. Car Parks

Figure S2 shows the infrastructure of an electric vehicle charging car park, which has several hundred charging stations. The car park features similar charging stations to those found in the home, with the primary difference being that, rather than maintain a direct connection of 3G/4G to the charging provider's

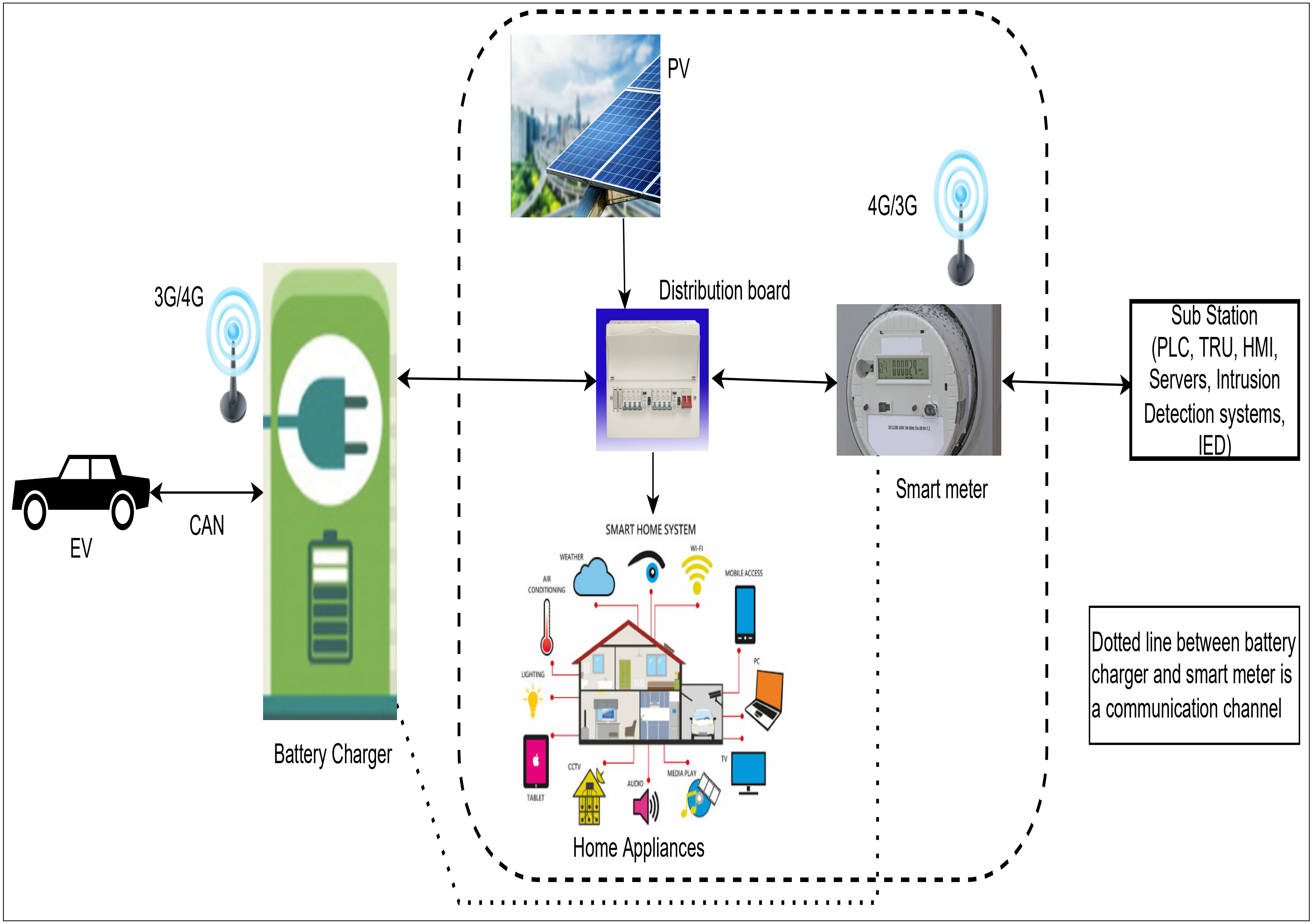

Fig. S1. Electric Vehicle (EV) charging connectivity at Home.

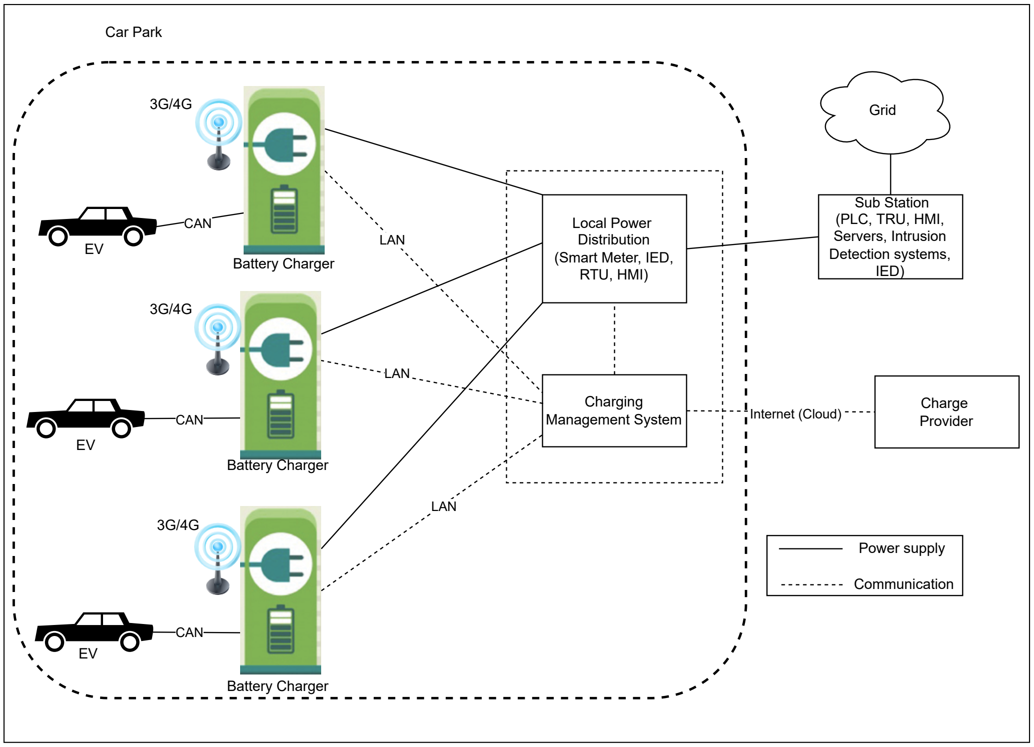

Fig. S2. Electric Vehicles (EVs) charging connectivity at Car Park.

infrastructure, the chargers connect to a local Charging Management System (CMS) over a local wired LAN. The CMS acts as a gateway to the carpark, and provides a connection to the charging providers infrastructure. As well as acting as a gateway for the individual chargers (and connection to smartphone applications), the CMS can monitor the energy usage of the car park through a connection to the local power distribution unit. The power distribution unit acts as a local substation specifically for the car park's charging infrastructure, and contains SCADA equipment (an RTU which is accessible to the charging provider through the CMS and local HMI), as well as a smart meter for the energy provider for billing the used electricity from the grid.

C. Power Networks

Figure S3 shows the power supply from smart grid to EVs at home and EVs at car park. Power flow is bi-directional at each place. When the power is in excess at home (EV + PV), it is possible to sell it to the sub station. Although this power exchange can be bidirectional, the grid-to-vehicle (G2V) direction is more common and the vehicle-to-grid (V2G) direction is limited to relatively small- scale pilot projects and implementations. However, it is projected that V2G services will become more wide spread in the near future, especially in regions with near-term deep-decarbonization goals.

D. Communication Networks

Figure S4 shows the key communication networks within the EV smart grid scenario. Each premises that contains a smart meter, which uses a 3G/4G

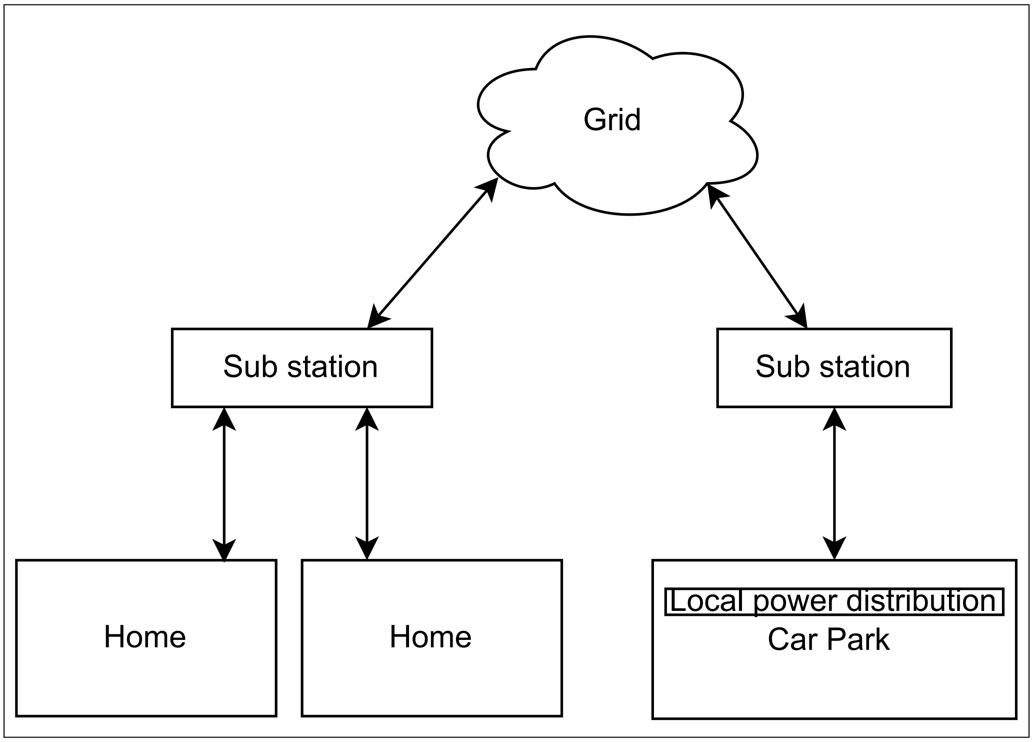

Fig. S3. Overview of the power supply

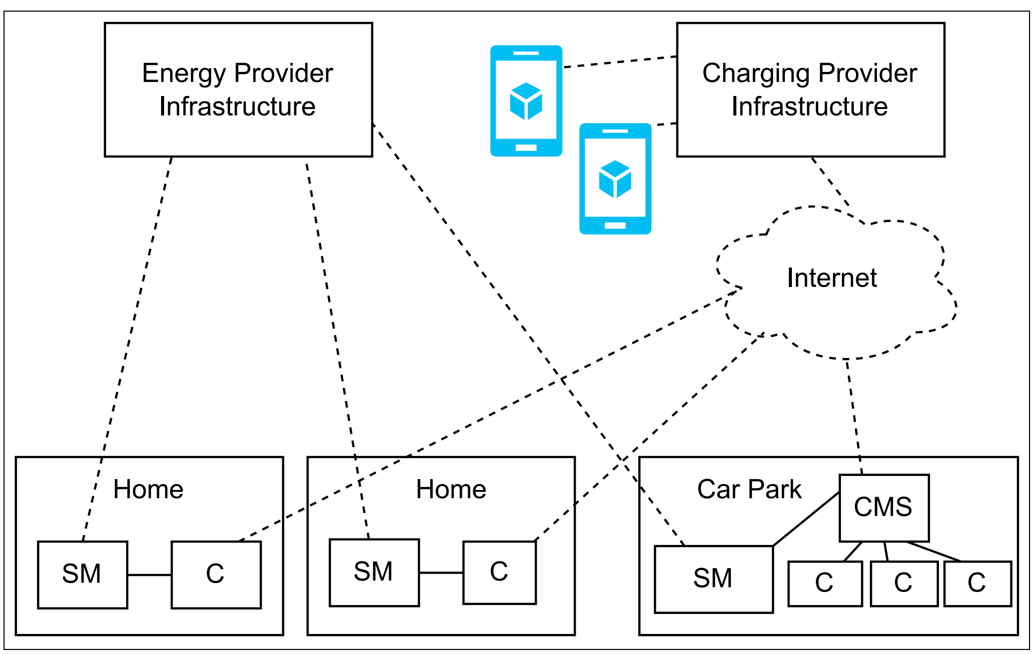

Fig. S4. Overview of the communication channels; Here SM is smart meter, C is charger or battery charger, CMS is charging management system.

radio to communicate with the infrastructure of the energy provider. The primary use for this communication is to send usage data (meter readings) to the energy provider to be used for billing and monitoring. The smart meter also reports the energy provided back into the grid so that the user can be credited. The energy provider can, if required, use this channel to remotely disable the energy supply to the premises using the smart meter. Within homes, the smart meter maintains a connection to the EVCS in order to monitor energy usage, and measure stored energy. Within car parks, the smart meter in the local distribution unit communicates with the CMS in order to measure storage capacity and energy demand.

The charging provider maintains their own server infrastructure for billing and monitoring, which sits in the cloud. For home installations, EVCS maintain a 3G/4G connection to this infrastructure for monitoring and providing the capability to the smartphone application. The provider maintains a connection to CMS stations over a typical broadband connection. Within a car park, the CMS is connected to EVCS over a local LAN, which replaces the 3G/4G radio.

All EVCS use the CAN protocol to communicate with vehicles. The CAN protocol uses a serial connection built into the charging cables, and is used for collecting VIN numbers from cars for billing and authentication, as well as monitoring the satte of the vehicle whilst charging. The case study is designed based on [1]. For further details on EV security research look into articles [2, 3].

REFERENCES

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