DESIGN AND DEVELOPMENT OF A SMART URBAN MICROGRID FOR AN ELECTRIC LOGISTICS FLEET

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ABSTRACT

The paper discusses the design and development of an urban microgrid infrastructure for a logistics van fleet at a UPS logistics site in London, UK. The high-level system requirements are presented along with the technologies evaluated, which led to the system's architecture and finally the benefits that are achieved to support its business case.

INTRODUCTION

Decarbonising the transportation sector is pivotal for achieving greenhouse gas (GHG) emission targets and improving the air quality in cities. Transportation contributes ~25% [1] of the total EU-28 greenhouse gas (GHG) emissions with road transport contributing 73% [2] of the total transport emissions. Light and Heavy Good Vehicles (LGV and HGV) in the UK currently account for 30% of the road transport emissions and are projected to increase due to the growth of the goods moved [3].

Global mega-trends such as urbanisation, growth of population, economies and e-commerce along with sustainability targets pose significant challenges for logistics operators that rely on large fleets operations. United Parcel Service (UPS), the world's largest package delivery company, operate more than 112,000 vehicles including more than 9,000 alternative fuel and advanced technology vehicles [4].

In 2013, UPS joined the EU funded Freight Electric Vehicles in Urban Europe (FREVUE) project aiming to further increase their electric vehicle fleet in London and Rotterdam. In their central London hub, UPS discovered that the connection capacity of the site was not adequate to simultaneously charge the new electric vehicles, as the charging period coincided with the peak demand of the site (conveyor belts for package sorting). To tackle the constraint, the company decided to upgrade their local substation to enable the integration of 68 Electric Vehicles (EVs), a complex project that involved long discussions and agreement with the property owners and the local Distribution Network Operator (DNO). The cost of the project was in excess of £600,000 and the upgrade process took around two years [5]. The process highlighted that costly non-incremental capital investment, as well as disruptive and time-consuming network upgrades and investment into a third-party's asset could hinder the wider uptake of electric fleets.

Following the project completion in 2016, UPS tasked UK Power Networks Services to investigate the feasibility of applying smart-grid technologies to enable their full local fleet electrification without the need to reinforce the local network.

The study suggested that the development of an urban microgrid comprised dynamic EV charging coupled with an energy storage system (ESS) would achieve the most benefits for UPS and contribute to the decarbonisation of the transportation sector. In January 2017, the proposed system along with the investigation from the DNO of timed-connections and the conversion of UPS diesel vans to EVs was awarded a £1.2m grant from the Office for Low Emission Vehicles through a competition led by Innovate UK.

The system was commissioned in February 2018 and extensively tested until March 2019.

This paper describes the system's requirements, the technologies assessed in the feasibility study and the system's architecture and capabilities.

SYSTEM REQUIREMENTS

The UPS logistics site located in central London is UPS's main distribution hub for London with 170 LGVs operating within it to deliver goods in the city. Currently 52 EVs operate in the specific site. Their 66kWh battery charging process is initiated when the vehicles return to the depot, typically between 16:00 and 21:00 and are expected to be fully charged by 08:00 of the next day.

Technical requirement

The system should enable the full charging of 170 EVs within a time window between 20:00 and 08:00 of the next day, while all site operations continue uninterrupted with the local connection capacity being limited at 1250kVA.

Future-proofing requirements

Given the rapid advances in Lithium-Ion batteries, an increased average battery capacity of the 170 vehicles should be calculated (71kWh). In addition, due to the growth of the package delivery market, a 10% increase of the site demand should also be considered.

Business continuity requirements

The developed system should be an integral part of UPS's operations and incorporate fail-safe mechanisms to ensure that the vehicles will fully charge even when component(s) of the system fail or are unavailable. In addition, the development and installation of the system should not affect the on-site business operations.

Economic and environmentally friendly

The developed system should have a lower implementation cost when compared to traditional reinforcement and should consider alternative technologies that are aligned with UPS's sustainability targets.

FEASIBILITY STUDY AND TECHNOLOGY ASSESSMENT

The feasibility study that was carried out analysed the current-on site demand and modelled the impact on the integrating additional 118 electric vans. It also investigated different smart-grid technologies and concluded with an optimal system design which satisfies the technical and commercial requirements.

Energy consumption analysis

Figure 1, illustrates the demand profile of the site's load. During evening times, the demand peaks due to the charging of the EVs and the auxiliary loads of the site. The dark area in Figure 1 indicates that there is additional capacity, which could be used to enable further EV deployment on site. However, since the depot building demand is uncontrollable, the flexibility of the system lies with the charging strategy of the EVs.

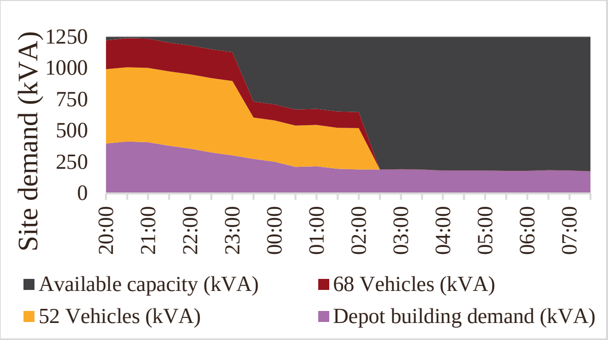

Figure 1. UPS's Camden site demand

Technology options analysis

The various technology options and smart charging strategies that have been evaluated to realise the solution requirements are outlined below:

1. Reactive smart EV battery charging

A reactive EV charging regime incorporates the use of load limiters. Load limiters can be configured to be **static** without the ability of varying the limit over time or configured to **dynamically** adjust their limit . The load limiters could be applied at the following locations:

1. Load limiter per EV charging point
2. Load limiter per group of charging points
3. Active Network Management (ANM) for the whole EV fleet

2. Proactive smart EV charging

This option offers the ability to schedule the process of EV charging, taking into account the available capacity and the preferences of the EV users/ owners. The software systems that could deliver this functionality would use the following data inputs:

1. Static or dynamic constraints of the available infrastructure
2. Vehicles' State of Charge (SoC) at the time of connection, desired SoC at the time of departure and time of departure

3. Smart EV charging and ESS

The above Reactive and Proactive EV charging strategies could be combined with the use of energy storage that can deliver additional power/energy during periods of high demand and enable a smoother EV charging session for the vehicles. There are different schemes that can be delivered when combining the two technologies as shown in Table 1.

Table 1. Integration options for the smart EV charging and ESS

Two platforms in isolation	**Coupled platforms**	**Fully integrated platform**
-Simplicity	-Can unlock additional benefits	-Can unlock additional benefits -Can be scaled for different sites
-Complicated when capitalising on additional benefits	-Interface between the two systems required	-Lengthy, complicated and costly implementation

4. Smart EV charging and energy storage, including route and multiple locations consideration

This option investigated the benefits of migrating the UPS's scheduling systems with the smart charging system to optimise the charging strategy based on the miles that the different vehicles have been scheduled to travel the following day.

Comparison of options and recommended solution

The different options were assessed against a set of criteria to identify their suitability. The comparison results is shown in Table 2. The reactive smart EV charging options were excluded from the comparison as the technology could not deliver the expected functionality due its limited flexibility.

Table 2. Comparison of technology options investigated

Option	**Simplicity**	**Future-proofing**	**Innovation**	**Business disruption**
1.	Medium	Medium	Medium	Low
2.	Low	High	High	High
3.	Medium	Medium	High	High
4.	Low	High	High	Low

Option 3 (Reactive dynamic smart EV charging with

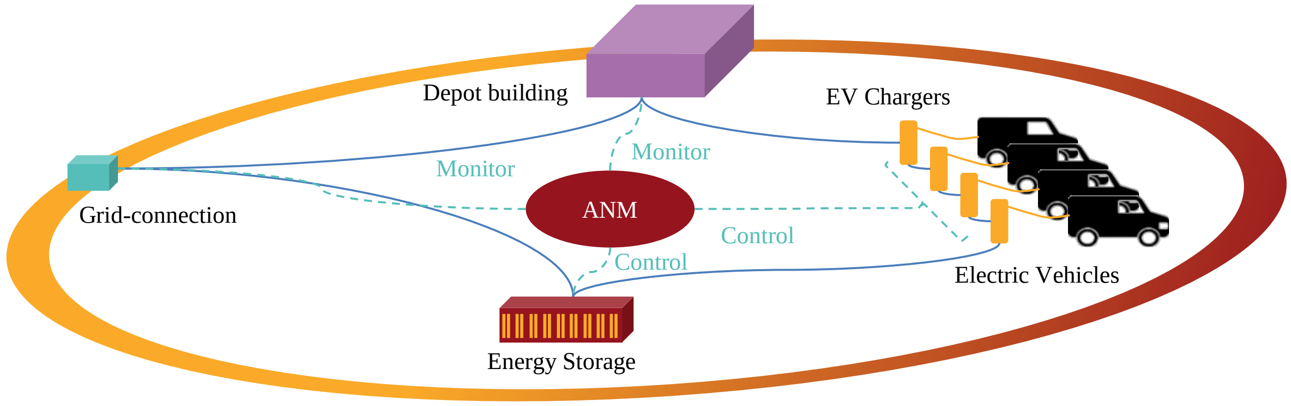

Figure 2. Conceptual illustration of the recommended system for the UPS site in Camden, London

energy storage) was recommended as the optimal solution to unlock the flexibility required and enable the integration of 170 EVs, with short implementation timescales and acceptable implementation risks.
The conceptual solution recommended is illustrated in Figure 2.

SMART ELECTRIC URBAN LOGISTICS (SEUL)

In April 2017, the implementation of the Smart EV charging system commenced as part of the SEUL project. The project was split into two main phases ; the first year (April 2017 – March 2018) covered the specification, design, development, installation and commissioning, while the second year (until March 2019) covered the system's trials.

Smart charging system architecture & interfaces

The communication architecture of the developed system is illustrated in Figure 3. The system comprises the following interfaces ; metering equipment, ANM system, energy storage system and the electric vehicle fleet.

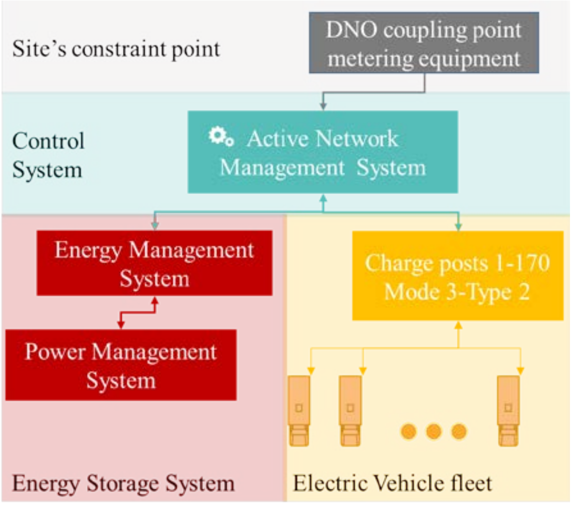

Figure 3. Communication architecture and data flows between system's interfaces

Metering equipment
The metering equipment installed on site was designed to transmit a set of electrical data in a second granularity.

ANM system
The ANM software is the core of the developed system, communicating with all system's components in order to retain the demand within the specified limit.
The system receives the following key information from system's interfaces:

Metering equipment: Total power consumption of the site (kVA)

ESS: Power injected/consumed (kW, kVAr), operating mode, SoC (%)

Charge posts: status (vehicle connected/charging, charging rate, energy consumed in a charging session)

When the on-site load gets close to the capacity limit the ANM can control the following interfaces:

ESS: The ESS receives a dispatch command from the ANM with the setpoint of the power required to relieve the constraint

Charge posts: Each charge post can receive a command to reduce its output power as necessary. This is then communicated to the vehicle on-board battery charger and the vehicle reduces the power consumed as commanded.

Since the SoC of the vehicles cannot be extracted from the Type-2 connector (IEC-61851) the system assumes that all vehicles had the same SoC (0%) when they were connected and calculates the total energy that has been delivered during a charging session in order to prioritise which vehicles should be curtailed first and calculate the curtailment strategy.

Respectively, when the on-site demand falls under a specific threshold the system releases any curtailment or dispatch commands that have been issued to the charge posts or ESS.

ESS
The ESS has two main operational modes; manual and automatic. Under the automatic mode the ESS is receiving dispatch commands from the ANM system, while under manual mode the asset can deliver other services as an independent system. The services that can be delivered from the ESS are the following: peak shaving, energy and power injection/absorption,

frequency regulation and voltage regulation.

Additional system's modes

The system has been designed to fully charge 170 vehicles from 0% to 100% state of charge. However, it has been observed that most of the EVs return to the site with a SoC ranging from 15% to 50%. This can unlock additional benefits and further support the business case of the smart charging system. Thus, different modes will be developed during the project to capitalise on these benefits and evaluate their value. These modes are discussed below.

Energy offset

Energy price plans can include different rates for electricity between day and night. In the UK, Economy 7 plans offer cheaper electricity rates typically between 10.30pm and 08:30am. This aligns with the typical charging session of the EVs, which means that offsetting the demand after 10:30pm can contribute to significant benefits.

Ancillary services

Frequency response: The GB System Operator procures services to assist with balancing the system. As the vehicles can be charged at different rates, this gives the system flexibility to increase or decrease the demand as mandated by the frequency levels. While this service can be delivered with G2V technologies, it can be further enhanced through an implementation of a V2G system.

Demand turn-up: The GB System Operator procures this service during periods of low demand and high renewable generation (typically during summer night-time). The smart charging system has the capability to set a standard charging rate to a lower than 11kW and increase it to 11kW when commanded by the system.

Case study: Energy offset benefits

Assuming a 170 EVs fleet returning on site with an average 30% SoC and an dual tariff supplier contract (cheap tariff 22:00-08:00 at 7.1p/kWh and peak 15.1p/kWh), a £110 cost saving is calculated for a single charging session. Assuming a 6 day operation of the fleet the energy offset can lead into a £35k/annum cost saving.

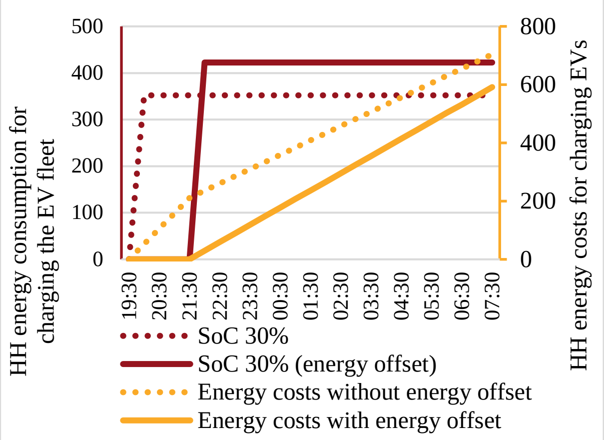

Figure 4. Half-hour energy consumption and costs during a typical night charging session

GENERALISED COST BENEFIT ANALYSIS

The DNO reinforcement costs, implementation times and related parameters such as the land ownership of the site vary dependent on location. Similarly, the costs of a smart charging system depends on the technologies utilised, software sophistication and scale. A 10 years financial analysis for a generalised system with a similar size to the UPS project is presented in Figure 5.

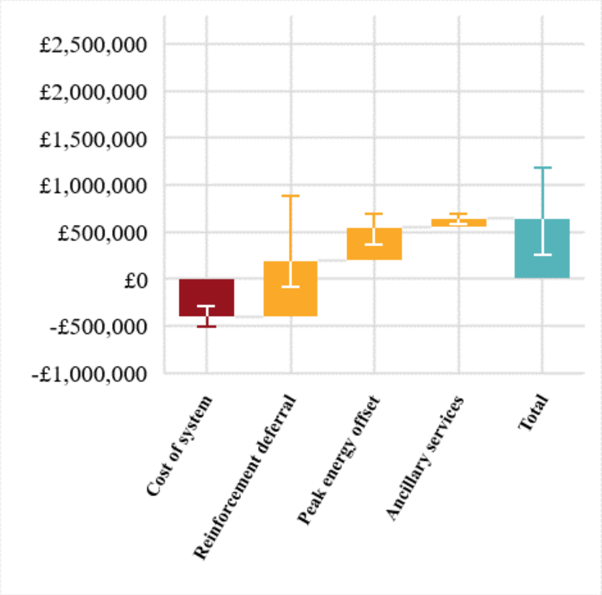

Figure 5. Cost benefit analysis of a generalised smart charging system

As can be seen in the graph the implementation of the smart charging system is cost competitive, due to cheaper implementation costs and the additional benefits.

REFERENCES

[1] European Environment Energy. 2017. Greenhouse gas emissions from transport. [ONLINE] Available at: https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-10. [Accessed 12 March 2018]

[2] European Environment Energy. 2017. A European Strategy for low-emission mobility. [ONLINE] Available at: https://ec.europa.eu/clima/policies/transport_en. [Accessed 12 March 2018]

[3] Department for Transport. 2017. Domestic Road Freight Statistics, United Kingdom 2016. [ONLINE] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/627597/domestic-road-freight-statistics-2016.pdf. [Accessed 12 March 2018]

[4] UPS. 2017. UPS Fact Sheet. [ONLINE] Available at: https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=FactSheets&id=1426321563187-193. [Accessed 12 March 2018]

[5] Tanja Dalle-Muenchmeyer. 2014. Electricity grid infrastructure upgrade. [ONLINE] Available at: https://crossriverpartnership.org/media/2017/02/FREVUE-UPS-case-study_infrastructure1.pdf. [Accessed 12 March 2018]