Start Vehicle Workings with Optimum Charge Levels

How IVU's automatic charging management ensures up-to-date vehicle data and reliable ranges

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Target state of charge, departure time, age of the battery, available total capacity, operational charging stations, and energy costs: Transport operators must take many aspects into consideration when planning the charging of electric vehicles. Each vehicle and each depot requires the correct charging strategy. This is the case for example with the fleet of electric buses in Duisburg, which is operated by the Duisburger Verkehrsgesellschaft AG (DVG) using the integrated load and charging management system from IVU.

Since 1st March 2022, the DVG deploys seven articulated buses and is thereby able to operate the route 934 entirely electrically [1]. Deployment of these environmentally friendly electric buses saves around 1,000 tonnes of carbon dioxide (CO_2) and simultaneously ensures a significant reduction of pollutants and noise emissions in the city. The latter was one of the motivations that led the DVG to electrify bus transport on the 934 route. As is well known, the bus route leads from the Unkelstein depot through the city centre to the Six Lakes area in the South of Duisburg, thereby passing through districts considered burdened by noise and pollution. These should profit in particular from the direct improvement of the air quality [1].

To implement the migration of operations on the 934 route to electric buses, the DVG receives subsidies from the Federal Ministry for the Environment and from the Rhein-Ruhr (VRR) [2]. The Daimler subsidiary EvoBus GmbH delivered the seven articulated, eCitaro type buses necessary. The required total capacity of 330 kWh is comprised of the 10 high-voltage battery assemblies of the newest generation of lithium-ion batteries (NMC2) with higher energy density [2]. EvoBus also appears in the project as a technically and commercially responsible general contractor and is responsible together with its partners and subcontractors for the vehicles, charging management, and the peripheral devices, including the charging technology.

During operations, the vehicles can be charged with a pantograph on the front carriage at the charging infrastructure of the SBRS GmbH (Schaltbau Refurbishment Systems) at the DVG depot Unkelstein [2]. The turnaround times at the end stop "Betr. Am Unkelstein" are used for intermediate charging at two 450 kW rapid chargers at a T-mast (Figure 1) outside of the depot [3]. Additionally, the SBRS installed seven stationary charging devices for night deployment with contact hoods and a maximum capacity of 150 kW in the parking hall.

Figure 1: Opportunity charging of two EvoBus eCitaro G at the 450 kW rapid chargers [1] (Image: DVG)

For monitoring and control of the charging processes, the DVG uses the integrated load and charging management from IVU Traffic Technologies AG (IVU) [4], [5]. With this software system, need-based charging schedules can be automatically created using the departure time point, and the charging infrastructure can be controlled by means of smart charging phases. The punctual preconditioning of the passenger space as well as the load limits are also taken into consideration when calculating the charging schedule [5]. Additionally, the charging management system (CMS) is connected to the Daimler Buses data interface. The dispatch managers of the DVG are therefore able to monitor all relevant vehicle data, such as the state of charge and the remaining range, in real time via the Daimler Buses cloud directly in the software system [4].

Charging Management System for Bus Operations

IVU's load and charging management comprises selected functions of the integrated depot management system for electric buses and is therefore specially tailored for bus operations. Together with the module for calculating charge schedules, charge phases are defined and conveyed to the charging devices via Open Charge Point Protocol (OCPP). Besides battery charging, phases for supplying secondary customers, for balancing the batteries and for preconditioning can all be scheduled as well.

Fulfilling the operational guidelines of the DVG – and thereby guaranteeing stable operations – is the highest priority when scheduling charging. The individual steps of the charge scheduling are displayed in Figure 2 – from determining the operational guidelines through to the optimisation of the charge phases.

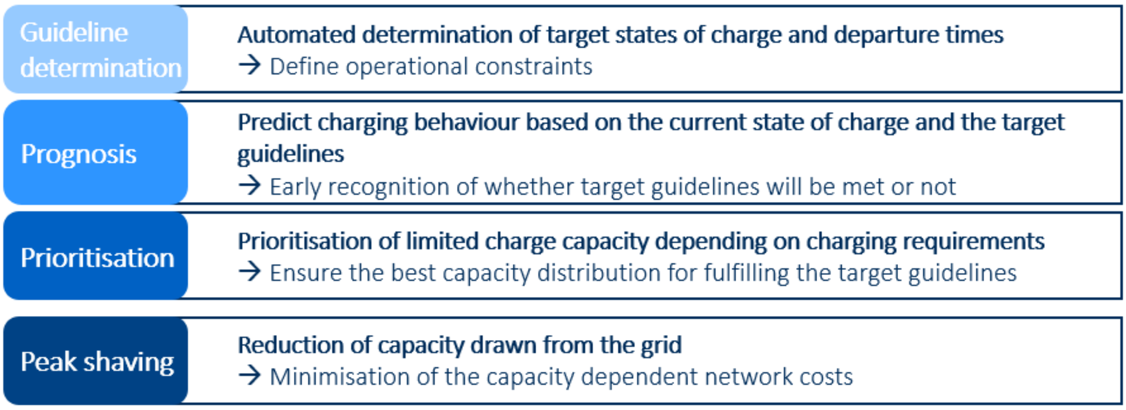

Figure 2: Smart Charging Functionalities (Graph: IVU)

The essential guiding principles in charge scheduling are operational guidelines in the form of a target state of charge and a departure time. In practice, it is not practical for a user to manually determine the target values for each charging process. Instead, an automatic process is required. In IVU's CMS, three different solutions to accomplish this are implemented, differing in their degree of detail. A rule system defines the specification of charging targets with which target values can be defined depending on the charge point, the vehicle, and the time period when charging begins. Instead of the rule system, a presystem (e.g. a depot management system or a control centre) can be connected via the VDV 463 interface, which then transmits the target values. The most comfortable variant is the use of the integrated electric bus depot management system (eBMS), which determines the target state of charge and the departure time based on the current utilisation of the infrastructure and the planned vehicle workings [6].

The next step is the use of technical models of the infrastructure and the vehicle battery in order to illustrate the charging behaviour. Whether each vehicle will be able to reach the scheduled target state of charge at the predefined time point, and the level of capacity required to accomplish this, can already be determined in this step. It should be taken into account here that the charging behaviour is by no means linear and can significantly differ, depending on the battery type. Furthermore, how far battery ageing has progressed must also be considered.

Adhering to the Capacity Limits

The power grid connection and the downstream power supply infrastructure in Duisburg is structured in such a way that reserves for the extension of the electric bus fleet are already available. All currently obstructed charging devices could simultaneously require their full capacity without overburdening the power grid connection. Should this no longer be the case following the further build-out of the network, the prioritising functionality of the CMS takes over. To maximise operational stability, capacity is preferentially assigned to vehicles that have the highest charging requirements. Vehicles that stop at the rapid charging spaces during the day are thereby more highly prioritised than simultaneously present parked vehicles, which will be deployed later the following day.

In addition to the static capacity limits that result from the dimensions of the infrastructure, dynamic capacity limits can also be defined in the IVU's CMS. This offers the opportunity to reduce the capacity drawn from the grid and thereby to save on network costs (atypical network use), in particular during periods of high load.

Limit Costs by Peak Shaving

Ensuring stable operations is the primary goal of the charging management system. In addition to this, however, there is potential for further optimisation, which can positively influence the costs of operation. Peak shaving functionality is a central point. This term refers to the ability to smooth load peaks. This is done by temporally shifting the charge phases and by reducing the charge capacity. The energy needed to charge the electric buses is thereby supposed to be drawn from the network as evenly as possible – because the lower the peak capacity required, the lower the capacity-based network costs. The capacity at the power grid connection averaged across each 15 minute interval is the decisive factor in determining the electricity bill for the year. Positive side effects include the minimisation of losses and conservation of vehicle batteries [7].

Monitoring the Charging and Operation of Electric Buses

If the load and charging management system is correspondingly setup and configured, it only requires a few manual adjustments. As soon as a vehicle connects to a charge point, the charging management system automatically calculates a suitable charging schedule based on the current battery capacity using the entered target parameters and general conditions. The smart charging phases of the charging schedule are then transferred via OCPP to the charger and implemented there when charging the vehicle.

Using IVU's charge point monitor (see Figure 3), DVG's technical charging infrastructure personnel can monitor active charging processes at all times. The charge point monitor displays the availability of charge points, communication interruptions, and charger errors. During an active charging process, the connected vehicle and details on the current condition of the battery charge level as a percentage, as well as other key performance figures, can be displayed. These key performance figures are recorded for each charging process and can then be exported in the form of statistics.

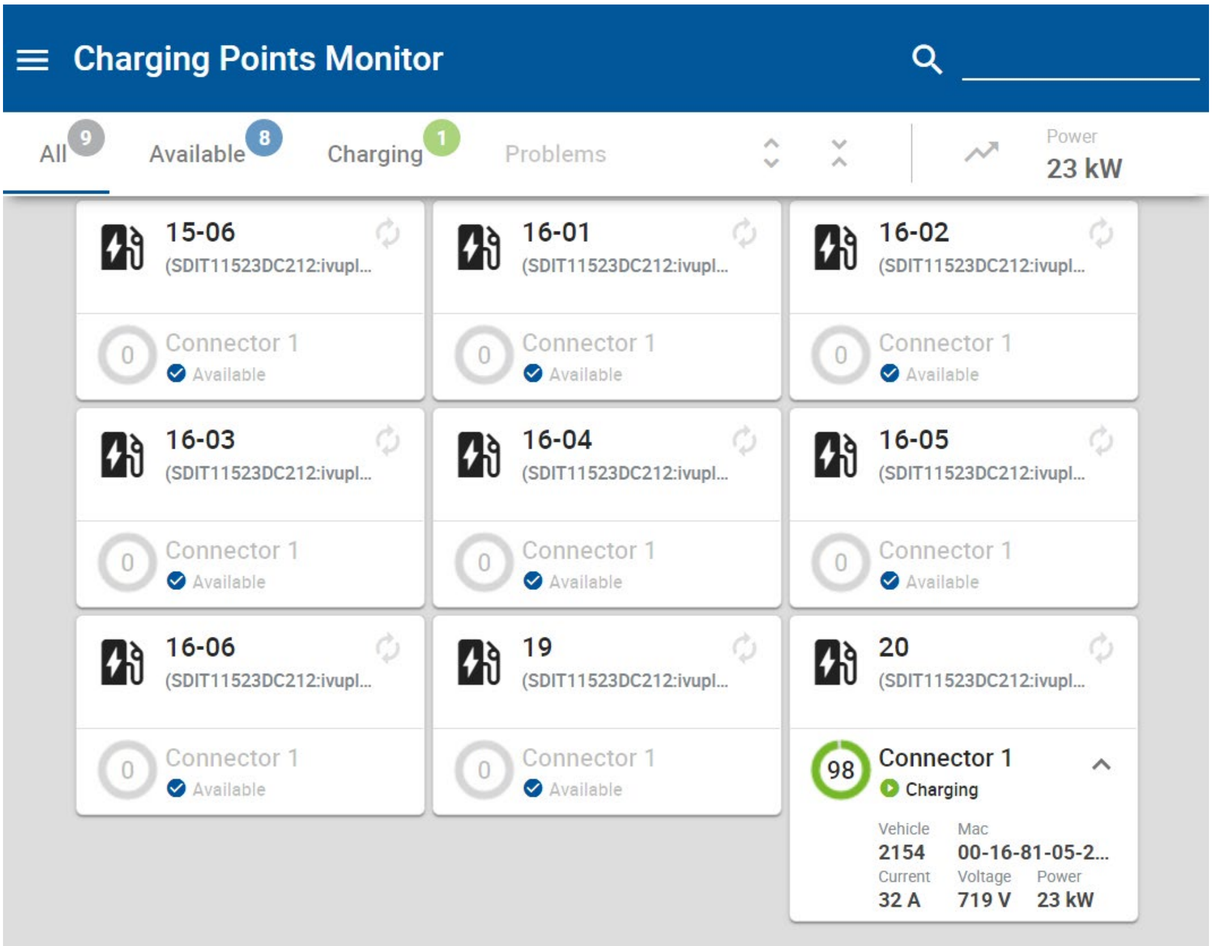

Figure 3: IVU Charge Point Monitor: Technical view for monitoring active charging processes (image: IVU)

If the connection is interrupted or a charging error is reported, those responsible for the charging process can be notified of these warnings per email or SMS. Often, simple disruptions can be resolved by a remotely initiated OCPP soft reset in the charge point monitor, avoiding the necessity of travelling to the charge device to resolve the error.

If the vehicles are on a link during route operations, the relevant key figures for electric buses – such as current state of charge of the battery and the remaining range – are displayed in a well organised table. The key figures are imported in real-time from the Daimler Buses cloud into the local IVU system. This information can be cleverly sorted and filtered for the respective purpose. By configuring the colouring of the vehicle data, critical states of charge can be easily recognised.

Course of the Charging Management Project

Although the beginning of the project as a whole took place at the end of 2020 – including the manufacture of the vehicles and the construction of the charging infrastructure – the subproject to introduce the charging management system only began in spring of 2021. In order to save time during initial operations, IVU and SBRS previously conducted remote test charges in June of 2021. These were carried out in order to confirm that the encryption, certificates and OCPP communication were correctly implemented, in order to conduct the default and smart charging plans of the CMS. Following installation of the CMS in the DVG server environment, the interfaces to SBRS and Evobus were configured. This allowed the necessary requirements to be created by autumn of 2021 for the CMS to be productively taken online directly after the finalisation of the charging infrastructure and the delivery of the seven eCitaros.

Supply bottlenecks, due to the pandemic, of an external manufacturer of medium-voltage switchgear caused the test phase of the integration of vehicles, charging infrastructure and charging management system to by significantly shortened. Nevertheless, all participating companies were able to stick to the scheduled starting date for the complete electrification of the bus route 934 on 1st March 2022. This frictionless and rapid course of project completion when implementing the CMS is due, among other factors, to the close cooperation and good partnership between EvoBus GmbH, here in the role of a general contractor, and IVU. Similar projects will profit from the experience gained here and can be even more swiftly completed in the future.

Future Opportunities

It makes sense to implement a feature-rich load and charging management system from the start, even for electric bus fleets which are initially of manageable size. With a CMS as a foundation, transport companies are prepared to further electrify their bus fleets and approach the goal of minimal-emission transport. The selection of manufacturer for the vehicles and charging infrastructure remains flexible. Hybrid operations, involving diesel, electric and hydrogen-powered buses also present no problem. Taking additional depots and end stops with new charging infrastructure into account merely requires the extension of the configuration of the CMS and can be carried out in a short period of time.

The integrative approach of IVU's load and charging management system easily enables additional electric bus modules from IVU.suite to be added – such as the electric bus vehicle working optimisation or the depot management system. The mutually-determining interaction between depot management and charging management enables vehicle working/vehicle allocations to be automatically carried out, not only based on vehicle type and attributes, or on depot and parking space features. It also enables the currently remaining battery capacity, the required energy of the following vehicle working, and different capacity limits of the charging infrastructure to be taken into account. Furthermore, the charge targets can be precisely adjusted to the following vehicle workings.This can be accomplished even under varying conditions which require dispatch-related measures at short notice. Using additional operational information, the charging management system can more efficiently distribute or withhold loads in order to optimally coordinate charging schedules across depots.

IVU's load and charging management system thereby offers a quick and ideal point of entry for the electrification of bus fleets. The flexibility and comprehensive compatibility of the solution offers the potential for a future expansion of the electric bus fleet and the charging infrastructure. The CMS thereby directly supports transport companies in the transition to a more environmentally friendly local transport and promotes the deployment of vehicles which contribute significantly to reducing noise and pollution in cities and thereby improve the quality of life in them.

About the authors

Simon Müller, chartered engineer, was employed as a Research Associate at the Technische Universität Berlin in the area of aviation and human-machine interaction after completing his degree in traffic systems. Since the beginning of 2019 he has been a Project Manager at IVU Traffic Technologies AG. As an expert in electromobility, he is most often involved in projects involving the introduction of charging and depot management systems or the optimisation of electric bus vehicle workings. Amongst other things, he directed the project at IVU described in the article to introduce the load and charging management system for the electric buses of the Duisburger Verkehrsgesellschaft AG.

Dr. Matthias Rogge, chartered engineer, one of the Managers at EBS ebus solutions GmbH, develops modules for the prognosis of energy requirements and charge scheduling with his team of software developers and engineers. Integrated into the complete IVU.suite system, these modules ensure that electric buses can be charged in a sparing, reliable, and cost-effective manner. Since 2015, he has advised transport companies throughout Europe in their transitions to electric buses with the ebusplan GmbH. Over the course of his dissertation at RWTH Aachen he had previously researched over more than five years in the area of battery system technology for electric buses and established a software supported process for system design.

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