Thinking about electromobility holistically

How does IVU.suite's integrated planning and control lead to optimal electric bus deployment?

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Shorter ranges, complex charging processes, and a charging infrastructure with limited capacity – electric buses present numerous new challenges for transport operators that can only be mastered with the help of specialised IT solutions. This specialised solution should ensure perfect rosters and optimum network utilisation during regular operation, and also provide solutions at any time in the event of a disruption. Using IVU.suite as an example, we describe the most important factors, and what this kind of system can look like below.

Regular Operation

The planning and operation of electric and diesel buses is integrated into the following three IVU.suite products:

– IVU.run for the vehicle working scheduling
– IVU.vehicle for the depot management system (DMS)
– IVU.fleet for the control centre (ITCS).

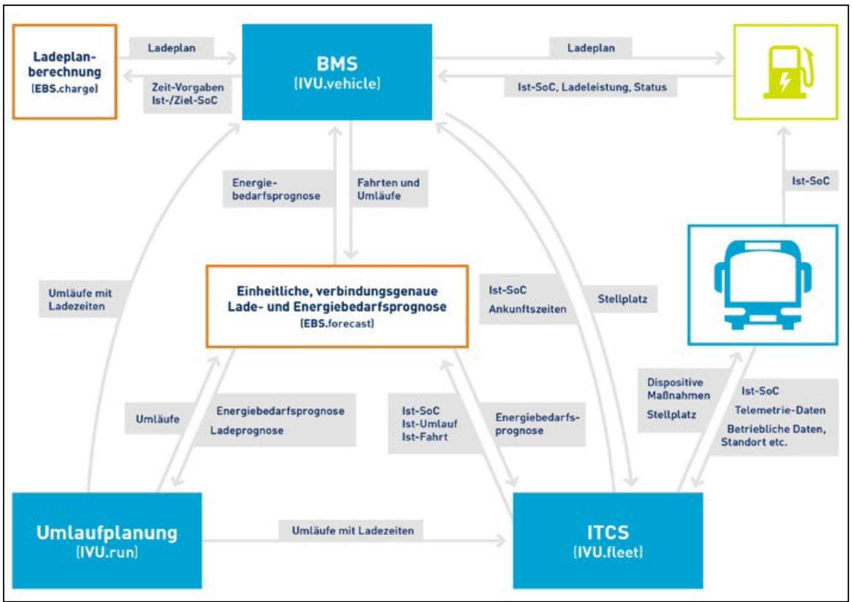

Fig. 1: Data flows for the operation of electric buses using IVU.suite as an example.

The IVU solutions integrate seamlessly with the products EBS.forecast and EBS.charge, developed by the company ebus solutions (a joint venture between IVU and ebus- plan) in close collaboration with IVU. This means that the prognosis data for e-buses comes from a single source at every step in the process, and is consistent – from the planning to the dispatch and operation. This consistency is important so that, for example, range forecasts have a common basis. In this way, you can avoid a situation where the depot management system assesses a vehicle working as drivable for a certain battery capacity, but this then directly generates a warning in the ITCS.

About the author

Dr. Claudia Hein (39) has a a doctorate in mathematics and has been working in product and project management for IT solutions for ten years. She has been working at IVU AG since 2015, where she was initially responsible for product implementationfor international bus and rail customers. She later took over the vehicle-based product management for IVU's planning and dispatch solutions. As part of this, she takes care of electric bus topics across different products.

About the author

Dr. Torsten Franke holds a doctorate in physics and has been working at IVU in Aachen since 2005, initially as a systems engineer and later as a project manager on national and international projects. Since 2010 he has been working in product management at IVU, where he was initially supervised for research projects and trade fair and sales systems. Among other things, he co-developed the IBIS-IP standard in 2014 and has made a name for himself as as an expert on ITxPT topics. Since then, he has taken on the responsibility of overall management of IVU's transport operation products.

EBS.charge and EBS.forecast are based on innovative modelling approaches and reliably provide the basis for operational decisions. EBS.forecast calculates prognoses for energy demand, charging behaviour, and battery capacity. In addition to the vehicles' technical properties, EBS.forecast takes all important influencing factors such as weather, route topology, and passenger load into account. Based on recorded consumption and charging data, the prognosis is readjusted with the help of self-learning algorithms and can also factor in battery aging, for example. EBS.charge generates charging schedules that allow for charging infrastructure restrictions. These could include the power limits of the power supply infrastructure, the charging devices' performance, and the current load on the power grid. In addition, the software accounts for takes time restrictions, such as locking periods. Each charging schedule prioritises the charging process that best charges the vehicle fleet and maximizes operational stability. At the same time, energy costs can be minimised through additional functions such as peak shaving.

Planning in Regular Operations

In vehicle working scheduling the optimal deployment of electric buses based on their range and energy consumption is key. Potential and required charging processes should always be taken into account. For example, the buses drive to the depot for charging or, if the infrastructure is suitable, then opportunity charging takes place at the relevant final stop points between the trips.

Most transport operators are aiming for a mixed operation of electric and diesel power for a longer period of time. For this reason, IVU.run's e-bus optimisation supports vehicle working scheduling in deciding which trips should be made with which type of fuel. The optimisation solution distributes the trips according to the available buses and predicts potential influences on the range with the help of EBS.forecast. Based on this, it then plans all the necessary charging phases.

DMS in Regular Operations

The depot management system has the task of optimally assigning all vehicle workings to the vehicles, taking into account the current vehicle states, such as the State of Charge (SoC) for electric buses. The DMS must manage the parked vehicles so that the activities to be carried out in the depot, such as cleaning or maintenance, can also be completed without any problems.

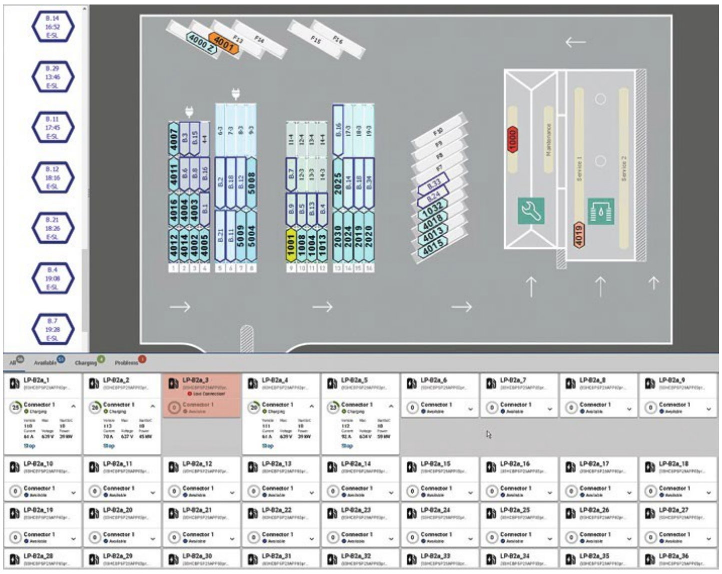

Fig. 2: Parking space view and charging point monitor in IVU.vehicle.

With IVU.vehicle, dispatch managers can automatically assign a parking space to entering buses, and assign the best possible subsequent vehicle working based on the relevant criteria.

Electric buses can be automatically assigned to parking spaces with charging stations. These parking spaces can be displayed directly on a depot entry display screen or on the bus. An automated recalculation of the charging schedule controls the charging processes with the integration of EBS.charge, so that all buses are charged to the required SoC until their next exit. The DMS takes the maximum capacity of the charging a bus that arrives late is assigned a higher charging capacity to prepare it for the next exit.

Since this kind of change can also affect buses that are already parked, all buses' requirements are taken into account in the charge schedule calculation, and modified as needed. The charging stations are controlled and monitored via the OCPP interface to ensure smooth integration here as well.

ITCS in Regular Operation

The ITCS not only ensures the operation of the entire fleet, but also guarantees that electric buses are always sufficiently charged for the scheduled vehicle working. Thanks to reliable vehicle working scheduling and flexible charging scheduling, the ITCS rarely has to intervene in regular operations. In addition, there may be increased consumption due to delays, extreme temperatures, or an increased number of passengers, for example.

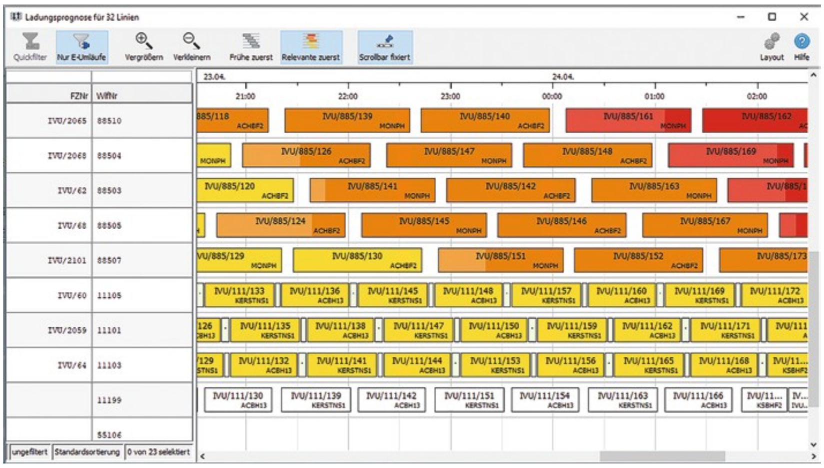

Fig. 3: Charging prediction: At a glance, a critical state of charge on a vehicle working can be identified.

In order to prevent electric buses' vehicle batteries reaching critical states of charge, it is necessary to monitor the SoC and the remaining range and to warn dispatch managers when certain threshold values are not reached. In addition, it is important to recognise emerging range problems at an early stage in order to have sufficient time for suitable countermeasures (e.g. other sufficiently charged vehicles taking over trips). The vehicle's technical and operational data (e.g. via the IVU.box/ IVU.cockpit on-board computer) must be appropriately linked with the information on the remaining vehicle working, which may have been modified in the dispatch (IVU.fleet), and with the expected energy consumption, taking into account relevant influences (EBS).

This linkage takes place in the charge (state) prediction (based on vehicle workings) in IVU.fleet. You can see at a glance If and when the charge status on a vehicle working becomes critical: Intelligent sorting functions mean that the vehicle workings that first enter a critical state of charge are always displayed as the top ones.

Disruption

How do the software requirements change in the event of a disruption? For example, let's consider the following scenario: A water pipe is broken on a major road, requiring a detour that takes several minutes. Many buses are affected and have to cover longer distances. It quickly becomes clear that the burst pipe cannot be repaired quickly, but will cause roadworks lasting several weeks.

This use case is already not easily mastered with a conventional fleet of diesel buses. The detour will lead to short-term delays, which may have to be responded to with cancellations or short turnarounds. Personnel must be rescheduled accordingly and passengers informed. If electric buses are also part of the fleet, the challenge is much greater and almost impossible to master without ideal integration of the individual programs.

ITCS in the Event of a Disruption

The travel path modifications for the affected routes, vehicles, and vehicle workings are set up in the ITCS. The drivers and the passengers are automatically informed about the dispatch modifications and potential delays. The state of charge prediction (see above) determines how these modifications affect the predicted state of charge for all remaining vehicle workings. The detour results in additional consumption which, in the case of some vehicle workings, means that the last trips can no longer be made safely. IVU.fleet displays the affected vehicle workings and trips with a long lead time, making it clear where there is an urgent need for action. Where possible, extended charging cycles at opportunity charging points are scheduled in the dispatch. Where necessary, the vehicle workings are also shortened by the affected trips via further dispatch-related measures. These trips are assigned to alternative vehicles. The DMS is informed about the modified arrival times and the expected SoC of the buses in the depot as well as about the necessary deployment of additional vehicles.

DMS in the event of a Disruption

At the depot, it is important to quickly find parking spaces for buses that arrive unscheduled – for electric buses with suitable charging infrastructure. IVU.vehicle helps here by automatically calculating a suitable parking space with the entry message and assigning it to the vehicle. This prevents expensive queues (which reduce the valuable charging time) from forming, or parking spaces from being blocked by inconvenient parking. In addition, the DMS automatically searches for suitable following vehicle workings and supplies the charging stations with a new, suitable charging schedule. Thanks to the close integration with IVU.fleet, the BMS also knows about the decreased SoC caused by the detour, making warnings before delays possible in good time. In the process IVU.vehicle ensures that no depot entry or exit blocks arise due to the allocation of the vehicle workings and parking spaces.

Planning for Disruptions

The vehicle working scheduling can react very flexibly to the new circumstances to be equipped for the duration of the detour. Creating a new route pattern makes it possible to adjust all affected trips efficiently. The e-bus optimisation calculates the optimum new distribution of electric and diesel buses and the charging processes on the basis of these changed trips. This can lead to shortened vehicle workings or to extended or additional charging phases between vehicle workings and trips. Alternatively, electric buses can be used more frequently on trips that are not affected by the detour during the roadworks. The optimisation makes the best choice from the various solution options with minimum manual efforts. The new planning can be transferred to the DMS and ITCS, so that no more short-term modifications due to the roadworks are required in the future.

Conclusion

Information must be exchanged between the solutions for planning, BMS, and ITCS, both during normal operation and when there are disruptions. Seamless integration is essential for this. A consistent prognosis of the energy consumption and the charging processes should be accessible at all times. Otherwise there are competing statements that complicate the daily work of everyone involved, particularly in the event of a disruption. The prognosis does not just need to be consistent, but also always accurate. Self-learning algorithms can help to automatically update complex prognoses.

Bus fleets will consist of both diesel and electric buses for a number of years. They cannot be observed in isolation, but must be taken into account in the planning, BMS, and ITCS simultaneously. In addition, the special features of electric buses in terms of operational requirements (e.g. range, or assignment of charging stations in the depot) must be given enough attention. The BMS gains importance through the connection to the control centre and the charging management, and supports parking in the right order whilst considering the charge point assignment.

There are various different challenges when deploying electric buses. Integrated IT systems reliably support normal operation, and help in the case of disruption.

<u>Summary</u>: Thinking about electromobility holistically

Introducing electric buses brings new challenges. The limited range and the need to plan and monitor charging processes leads to a new form of complexity. This makes the integration of vehicle working scheduling, depot management, and ITCS fundamental. Having a consistent prognosis for energy consumption and charge creates additional advantages. This is all offered by the integrated IVU.suite – the optimal IT solution for electric and diesel bus fleets.