Fig. 1: E-bus depot with a photovoltaic system and battery storage.

Fig: Depot with solar panels, AI-generated

E-bus depots: holistic charging and energy management system

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With the introduction of electric buses, bus operators face the challenge of actively managing electricity consumption whilst ensuring the usual levels of efficiency and reliability in operations.

Depot management systems (DMS) are primarily designed for the planning and allocation of vehicles to routes, but not for the control of charging processes. For this reason, charging management systems (CMS) have been introduced in the public transport sector. In conjunction with the DMS and the VDV 463 standard created for this purpose, the LMS performs two key functions: it receives the charging requirements from the DMS and uses them to create and control the resulting charging schedules.

Regardless of the requirements of the bus operations, there are established energy management systems (EMS) on the market, such as EnEffCo®, which are widely used outside the public transport sector and whose range of functions is constantly being further developed. The following sections introduce CMS and EMS along with their respective tasks and demonstrate how their interaction creates added value for transport companies.

Operational charging planning at the depot: the role of the CMS

The main objective of a CMS is to ensure vehicles are sufficiently charged. To achieve this, it must know how much energy a vehicle requires for departure to safely complete the next scheduled route or route chain. Up until departure, the CMS can flexibly optimise the charging process. In doing so, it takes into account peak loads at the depot, restricted periods, electricity prices, battery conservation and all other vehicles that need to be charged simultaneously – collectively referred to as smart charging.

New requirements such as electricity-price-optimised charging, which has already been implemented in IVU's CMS, increase the complexity of optimal charging planning. The key lever of the CMS in this regard is the concept of charging levels. A charging level defines at what power level energy is supplied to a vehicle over a given period. The combination of duration, power level and temporal distribution of these levels determines the overall charging behaviour in the depot.

The CMS may be constrained by load limits, an insufficient number of charging points, or too many vehicles charging simultaneously. To address this, the IVU

system allows the DMS to request a charging speed forecast from the CMS, in order to assess which charging targets can be achieved under the known constraints. If, for example, a load limit becomes active at the depot within an hour, the CMS informs the DMS of specific deviations from charging targets. The DMS uses this information to optimise the dispatching of vehicles on specific routes.

Holistic Energy Management: The Role of the EMS

The EMS provides a direct interface to all technical systems at the site as well as to the energy supplier. Thus, it lays the foundation for site- and depot-wide energy monitoring and reporting, as required by ISO 50001.

Consistent measurement data, transparent energy flows and reliable key performance indicators support documentation, continuous improvement and effective energy management in operations.

The EMS consolidates site-wide measurement and planning data to generate reliable forecasts of load, generation and flexibility at the site and determine performance limits and control signals for individual groups from these. In this way, the EMS enables the implementation of key optimisation strategies, such as reducing grid usage costs, maximising self-consumption from photovoltaic systems, and utilising dynamic electricity tariffs when charging buses. Even complex setups involving local electricity generation and storage or electrified heat generation can be integrated in this way.

Interaction between the CMS and the EMS

During operational use, the EMS dynamically adjusts the load limits of individual groups based on the actual overall situation at the depot. This dynamic peak load management ensures that grid constraints are reliably adhered to, without restricting operations. By passing the load limits to the CMS, a multi-stage load management system is created, which effectively prevents grid-side load peaks and thus sustainably reduces performance prices and grid usage costs. The EMS is also responsible for the sensor technology and control of the grid endpoints.

If a fault occurs, for instance, it is immediately communicated to the CMS. Load limits and information on the charging infrastructure are, as described, an important component of the CMS in order to be aware of the boundary conditions for charging. Once a fault occurs, the CMS is responsible for ensuring compliance with a new load limit and, if necessary, any changes to the charging power of the charging points.

When it comes to incorporating solar installations (PV) and energy storage systems in the future, control over power sources and load limits lies with the EMS, whilst the CMS retains control over the charging of vehicles. The CMS decides when and to what extent charging takes place; the EMS decides which power source can be used at what time, without the CMS needing to be aware of this. The CMS requires information on power limits and an electricity price. In this setup, electricity prices are not derived exclusively from current exchange prices, but also from past electricity prices (battery storage), other costs (solar systems) or a combination of both sources, for example, when a battery has been charged using solar and grid electricity. The CMS therefore receives a relative electricity price from the EMS, with the standard forecast period being 24 hours at 15-minute intervals. The CMS is thus continuously provided with an optimisation framework based on the forecasts, enabling intelligent charging planning that takes operational requirements into account whilst simultaneously minimising energy costs.

About the author

Dr. Kiraseya Preusser has been working in product management at IVU Traffic Technologies AG since 2024. Her areas of focus are electric vehicles and their impact on public transport systems. Prior to this, she completed her PhD at RWTH Aachen in electrical engineering, specialising in the modelling and optimisation of communication networks and electric vehicles.

About the author

Sven Jürgens, M.Sc. (Eng.), has been with IVU Traffic Technologies AG since 2023 and is responsible for DMS and CMS. He has been working in public transport for over 25 years, both as a software developer and as a project manager, including in the field of DMS for Stuttgarter Straßenbahnen AG and Hamburger Hochbahn AG. In total, he spent nine years as a division manager at PSI, where he was responsible for the development and implementation of DMS and CMS.

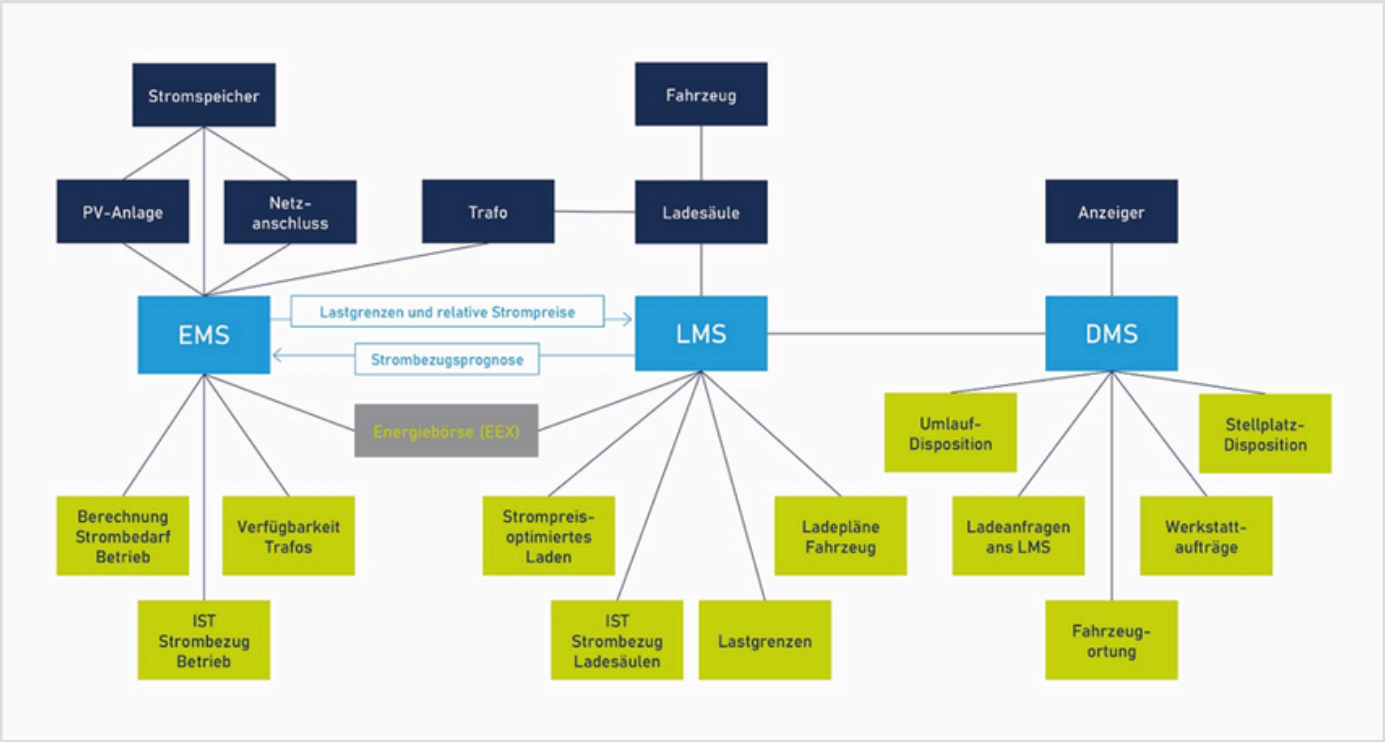

Fig. 2: System overview with core functions.

Fig: IVU Traffic Technologies AG

Conclusion

By delegating tasks – and thus the complexity of energy management performance control – to an EMS, the CMS can focus more closely on operational requirements and move closer to the DMS. This means that further differentiation into energy management-specific, costly specialised functions is not required.

Furthermore, experience with the interaction between CMS and DMS within the framework of VDV 463 already shows that the significant decoupling of both systems, combined with increasing complexity in implementation, is operationally disadvantageous. Topics such as dynamic electricity prices, simultaneous charging with multiple plugs and future bidirectional charging give an idea of how complex and expensive it is to implement under VDV 463. IVU's implementations to date demonstrate that a clear separation of responsibilities between CMS and EMS, along with a correspondingly streamlined interface, best supports operational reliability, economic efficiency and, ultimately, scalability.

Summary/ Zusammenfassung

E-bus depots: holistic charging and energy management

The close interlinking of the Charging- (CMS) and Energy Management System (EMS) is a central success factor for the future-proof operation of e-bus depots. CMS guarantees a demand-oriented, electricity-price-oriented charging planning and vehicle availability. EMS controls site-wide energy-flows, load limits as well as the integration of PV-plants and storages. A clear separation of responsibilities and a slim interface strengthen operation security, economic efficiency and expandability.

E-Bus-Depot: ganzheitliches Lade- und Energiemanagement

Die enge Verzahnung von Lade- (LMS) und Energiemanagementsystem (EMS) ist ein zentraler Erfolgsfaktor für den zukunftssicheren Betrieb von E-Bus-Depots. Das LMS gewährleistet eine bedarfsgerechte, strompreisoptimierte Ladeplanung und Fahrzeugverfügbarkeit. Das EMS steuert standortweit Energieflüsse, Lastgrenzen sowie die Integration von PV-Anlagen und Speichern. Eine klare Trennung der Verantwortlichkeiten und eine schlanke Schnittstelle stärken Betriebssicherheit, Wirtschaftlichkeit und Erweiterbarkeit.