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FAST-CHARGING TECHNOLOGY

Used to Electrify Construction Sites

DEUTZ®

Mobile Fast-charging Solutions for the Electrified Construction Site

Off the road, too, a contribution must be made to climate protection – not least in the construction machinery sector. Electrification of construction sites will play a central role in this. However, operators face the challenge of providing adequate charging infrastructure, often unavailable via the existing power grid. The PowerTree developed by DEUTZ is a mobile and robust solution that provides fast-charging capability without high grid power.

The recent environmental and climate policy developments and associated climate protection targets are paving the way for reducing CO_2 and noise emissions on construction sites and with other applications off the road. For example, the EU has created an initial basis for this with the regulation on including environmental aspects in the awarding of public contracts [1, 2]. Already today, several European metropolises have set dates from which the operation of construction machinery with internal combustion engines will be prohibited. As a result, the first emission-free construction sites are emerging [3]. Cities such as Barcelona, Helsinki, Copenhagen, Munich, and Oslo serve as examples. However, other countries outside the EU also promote defossilization and sustainability in the construction sector [4, 5]. In this context, additional potentials of zero-emission drives, which are particularly associated with electrification, often only become visible after implementation: a possible reduction in the size of supply and exhaust air facilities in civil engineering, a reduction in operating noise, as well as an extension of operating hours and the use of electric machines in sensitive areas [6]. However, the focus of all efforts is still on a high operational capability of the construction machines in all application areas.

NEED FOR MOBILE FAST CHARGING

Construction machinery must always be ready for use when construction progress requires it. For efficient use

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of the battery-electric vehicle, it is therefore essential to have a simple and fast intermediate charge as needed. This can be ensured by providing a fast-charging possibility.

The requirements of the construction site operators for the recharging process correspond to the refueling of a diesel vehicle: The process should be comparably fast on the one hand and comparably mobile and flexible on the other. To ensure smooth construction site operations, only the time windows during breaks and overnight are available for recharging. The energy required differs from the passenger car sector: For example, battery capacities between 100 and 500 kWh are installed in the 6-t to 21-t class. The locally required energy demand will thus increase continuously in the coming years due to the rising number of consumers and the increasing battery capacities in vehicles.

However, the infrastructure on construction sites has its limits. At most job sites, energy suppliers and construction site operators point out that only a construction power connection with outputs between 3.6 and 43 kW is available. **FIGURE 1** illustrates the associated challenge using the example of an electrified hydraulic excavator: Charging times for a full battery charge easily exceed 12 h, which makes full charging significantly more difficult, even overnight. As a result, due to the limited power supply and the resulting low charging currents, large battery-electric excavators (>16 t) can only be used efficiently with additional measures. On the other hand, medium-sized excavators (6 to 16 t) can be fully charged at night, but this is not possible during the break times during the day. To address this problem, DEUTZ has developed the PowerTree – a mobile fast-charging solution suitable for construction sites that does not require any complex adjustments to the power grid.

SETUP OF THE ENERGY STORAGE

The charging solution consists of a 10-foot container, which houses a charging station with up to 150 kW charging power. Battery stacks form a scalable energy storage system that can be permanently recharged via a conventional site power connection. The capacity temporarily stored in the batteries is released via one or two charging points. The charging points are designed as a standard Combined Charging System Combo 2 (CCS-Combo 2) per standard IEC 62196, meaning that vehicles from the automotive or on-road sector can also be charged, **FIGURE 2**.

Segment	Battery capacity	Charging power						Charged energy
	kWh	3.6 kW	11 kW	22 kW	43 kW	50 kW	150 kW	kWh
Small excavator < 6 t	10	2 h	36 min	18 min	9 min	8 min	3 min	6
	20	4 h	1 h	36 min	18 min	16 min	5 min	12
	50	9 h	3 h	2 h	45 min	40 min	13 min	30
Medium excavator 6-12 t	100	18 h	6 h	3 h	1.5 h	1 h	26 min	60
	200	37 h	12 h	6 h	3 h	3 h	53 min	120
Big excavator 12-21 t	300	55 h	18 h	9 h	4.5 h	4 h	1 h	180
	400	73 h	24 h	12 h	6 h	5 h	2 h	240

from 20 % ... Charging time ... to 80 %

Available in urban areas | **Limited** availability

FIGURE 1 Charging time in hours (h) for typical on-site charging power – example: excavator (© DEUTZ AG 2023)

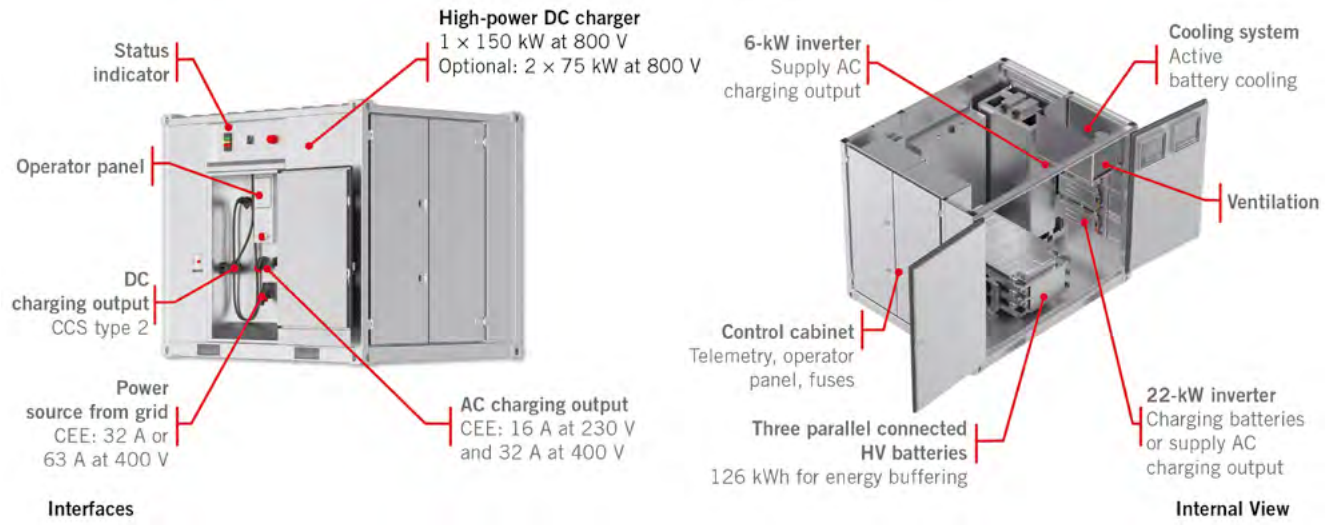

FIGURE 2 External interfaces and interior of the energy storage (© DEUTZ AG 2023)

Two modes can be used: on-grid and off-grid. With the first mode, the construction power is always available from the grid in the available connected power. Recharging of the internal buffer battery runs continuously and in parallel with the charging processes of the electrified construction machines. With the second mode, the connected power at the construction site grid is not available or only available with interruptions. In this case, the energy supply to the construction machines continues from the reserves of the buffer storage. In the standard variant, with a battery capacity of 126 kWh, an 8-t excavator can be supplied with energy in this mode for one to two days without a grid connection.

Another focus is transportability and the possibility of loading with lifting equipment commonly used on the construction site. Due to the standardized shape, the container can be moved on the construction site, for example with a forklift truck or wheel loader, or loaded or unloaded on a truck.

TECHNICAL CHARACTERISTICS

With a view to future construction site vehicles, charging voltages of 400 to 800 V have been realized and charging can be carried out simultaneously with different charging voltages. In addition, two AC outputs with 32 A/400 V and 16 A/230 V were installed, which serve, for example, as charging options for power tools and battery-electric vehicles that do not have a CCS interface. A standard CEE socket is used as the power supply, via which the PowerTree can be supplied with either 16, 32, or 63 A from the site power distributor, **FIGURE 3**.

Internally, two chargers provide up to 43 kW of charging power to the buffer batteries with a 63-A input. A selector switch offers the possibility to use one charger in off-grid mode as an inverter to provide an additional 400-V output with up to 22 kVA for balanced loads. In this mode, another inverter provides a single-phase 230 V at a maximum of 3.5 kVA. The buffer batteries, originating from the automotive sector, consist of the smallest version of three battery stacks with a gross capacity of 42.2 kWh each. DC/DC converters generate low voltages of 12 and 24 V from the batteries for the Programmable Logic Controller (PLC), cooling system, charge controller, and PC modules. While the PLC controls the sensors and actuators, a System Management control Unit (SMU) handles communication between the PLC, Battery Management System (BMS), charging electronics, and front end. If the operator authenticates himself at the front end using an RFID card, the data is transferred to a cloud via the mobile network using the OCPP-1.6 protocol. After authentication, the charging point and charging power are selected. Two charging points can be operated in parallel with up to 75 kW or one charging point with up to 150 kW. The charging electronics generate a DC link voltage of 690 V from the 400 V DC of the buffer batteries, which is subsequently regulated to the required output voltage of a maximum of 1000 V DC. Using an uncooled charging cable, the energy is transferred to the vehicle via a CCS interface.

Via a web app, a dashboard provides an overview of the status, the charging status of the connected vehicles, and the energy quantities delivered. An implemented billing management enables the administration of construction site customers.

TEST USE ON THE CONSTRUCTION SITE

Tests show that a fully charged lithium-ion battery, when used in an 8-t excavator with 100 kWh of battery storage on board, only needs to be recharged after about four hours. Analyses with operators show that normal break times are sufficient for charging and can be used. Charging during the lunch break takes place at up to 150 kW. This charges the electric vehicle's batteries from 10 to 90 % in about 45 min. This ensures that the electrified construction machine can be used until the end of the shift and that maximum capacity utilization is achieved. At the end of the shift, the electric machines are fully recharged overnight to be fully operational the next morning. This daily cycle is illustrated in **FIGURE 4** using the example of a hydraulic excavator.

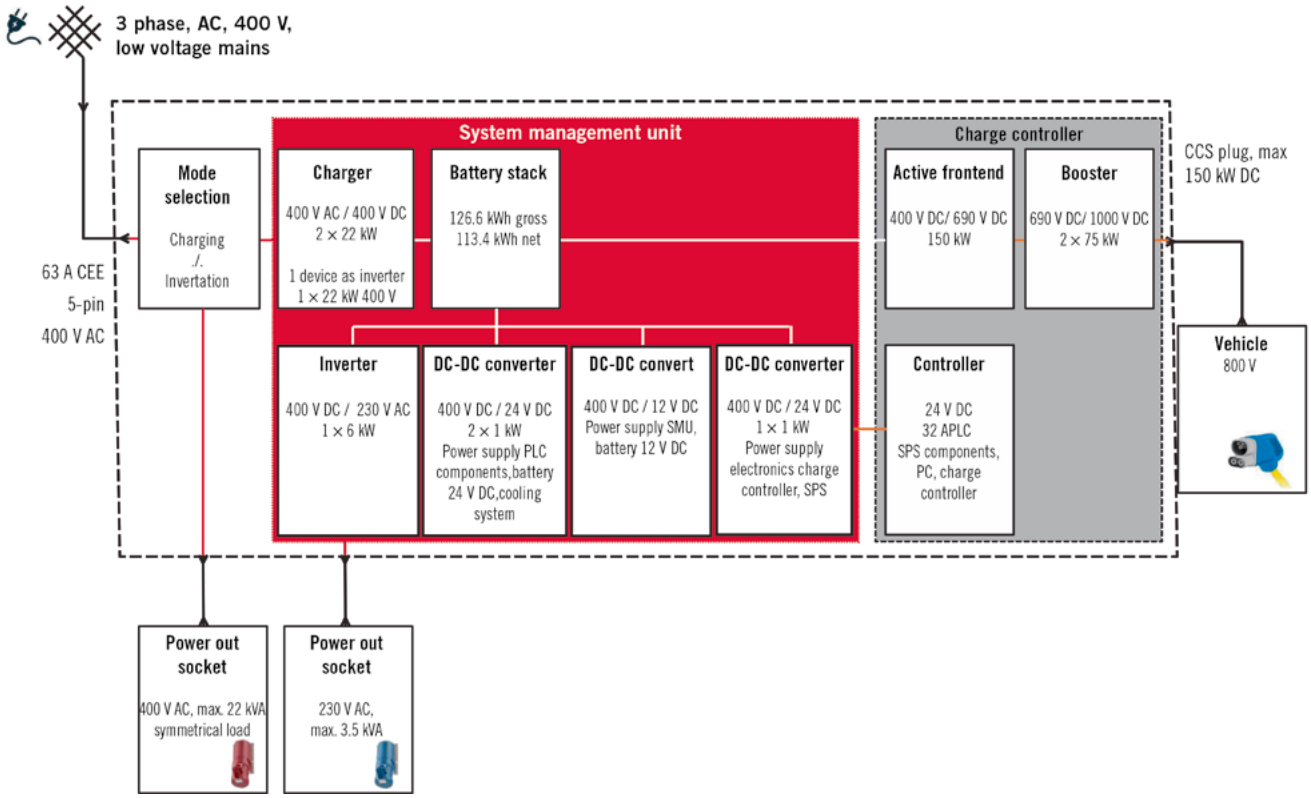

FIGURE 3 System diagram of the main electrical components (© DEUTZ AG 2023)

FIGURE 5 shows the interaction of the recharging process of a construction machine and the discharge cycle of the mobile energy storage using the example of two excavators in use, each with 100 kWh installed battery capacity and a PowerTree with 126 kWh gross battery capacity. The recharging of the vehicles is assumed in the example with a staggered lunch break of twice 45 min. By permanently charging the buffer batteries in the energy storage via the site power grid, high availability can also be achieved to charge several vehicles throughout the day.

CONCLUSION AND OUTLOOK

In the future, there will be virtually no way around electrified drive systems when it comes to establishing CO_2-free construction sites. However, a major challenge is the provision of a suitable charging infrastructure that can serve all consumers on the construction site. Conventional construction site power connections can only cover this demand to a limited extent. Charging solutions with intermediate storage units continuously recharged from the power grid represent one possible solution: The mobile fast-charging solution ensures permanent usability and an increased range of vehicles on the green construction site, in addi-

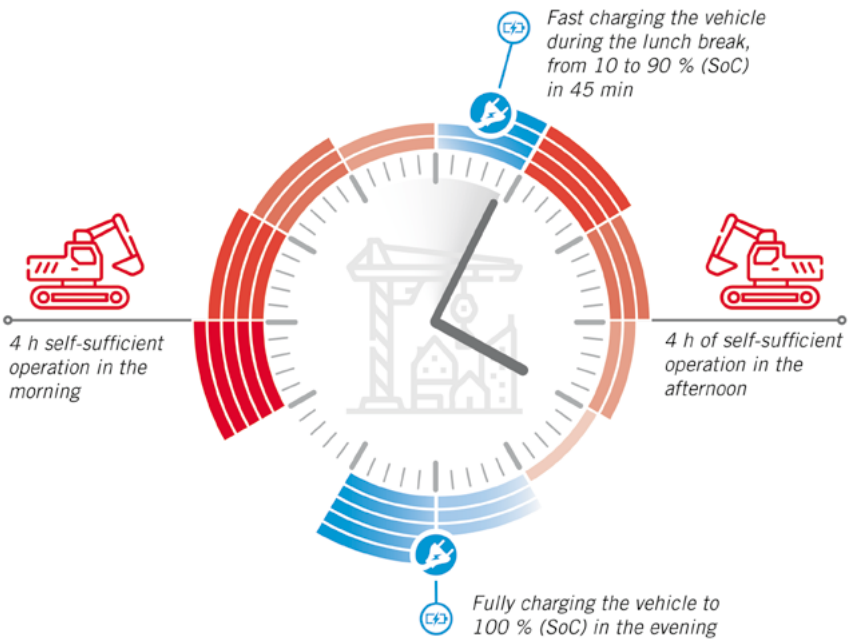

FIGURE 4 Exemplary representation of a working day with charging phases and working operation (© DEUTZ AG 2023)

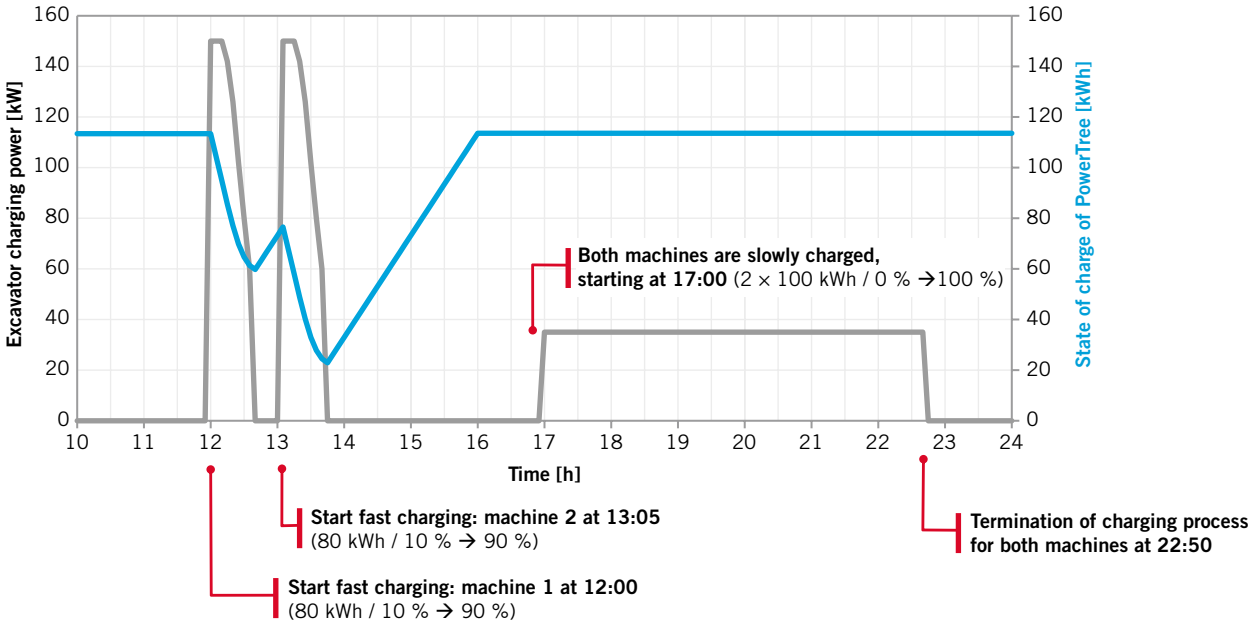

FIGURE 5 Recharging process of two electric excavators and charging cycle of the energy storage (© DEUTZ AG 2023)

tion to the future use of renewable fuels and hydrogen. The demand for ever higher charging capacities is becoming evident: While 150 kW was the state of the art at the beginning of the project, the need for charging capacities of 300 kW and higher buffer capacities of up to 500 kWh and more can already be identified on the market today.

The PowerTree is subject to continuous further development. While charging capacities of 150 kW were state of the art at the start of the project, customer demand for higher charging capacities of 300 kW and higher buffer capacities of up to 500 kWh and more are already apparent on the market today.

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