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DEVELOPMENT AND SUBSTANTIATION OF TECHNICAL PARAMETERS FOR AN INTELLIGENT MOBILE CHARGING STATION FOR ELECTRIC VEHICLES

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Abstract. *The rapid increase in the number of electric vehicles requires the expansion of charging infrastructure for their maintenance. In particular, the cost of building stationary charging stations, the need to connect to the power grid, the need for land, and the emergence of queues at charging points limit the efficiency of using electric vehicles in some regions. In this study, a technical concept for a mobile charging station with an accumulator energy storage system was developed as a complementary technology for stationary charging stations. The study determined the functional architecture, energy flow, battery capacity, DC charging capacity, energy efficiency, charging time, and service capabilities of the mobile charging station based on engineering calculations. The proposed basic configuration provides for the use of an accumulator battery with a nominal energy capacity of 120 kWh, a 60 kW DC charging module, a battery control system, power electronics, a telematic module, and an intelligent dispatch system. When the battery is assumed to operate in a charging state range of 15–90%, the available energy is 90 kWh. At a total efficiency of 94% of power electronics and cable circuits, the energy that can be transmitted to an electric vehicle is 84.6 kWh. One charging service, which requires 40 kWh of energy, takes an idealized time of 40 minutes, while a single operating cycle can provide approximately two full 40 kWh of service. The results of the study indicate the expediency of forming a mobile charging station not as a replacement for stationary infrastructure, but as a flexible energy-transport system that is in high demand, has limited charging infrastructure, and is used in emergency situations.*

Keywords: *electric vehicle, mobile charging station, battery energy storage system, DC fast charging, lithium-ion battery, BMS, power electronics, intelligent dispatching, charging infrastructure, electric vehicle transport system.*

Introduction

Electric vehicles are becoming an important segment of the global automotive market. According to the International Energy Agency, global electric vehicle sales exceeded 17 million in 2024, accounting for more than 20% of new vehicle sales. By 2025, global electric vehicle sales are projected to exceed 20 million, with a share of the new car market exceeding 25%. At the same time, in 2024, the number of ultra-fast chargers with a capacity of 150 kW or more increased by approximately 50%. These trends indicate that the demand for charging infrastructure is also changing qualitatively [1].

Stationary charging stations will remain a key element of electric vehicle infrastructure. However, their construction at all potential points of demand is not always economically and technically viable. A stationary station requires land area, connection to the power grid,

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transformer capacity, cable infrastructure, construction and installation work, and maintenance costs. A mobile charging station allows the charger to be transported to a location where there is demand.

In scientific literature, a mobile charging station is considered a charging system that has one or more charging outputs and can deliver energy to an electric vehicle at a convenient time and place for the user [2]. Afshar et al. divide mobile charging technologies into mobile stations based on trucks, portable chargers, and vehicle-to-vehicle energy transfer technologies [2]. An important feature of mobile stations is that they do not completely replace stationary ones, but rather expand their service area and mitigate the variability of demand over time and space.

Another important aspect of mobile charging is the possibility of viewing it not only as a charging device but also as a mobile energy storage system. Such a system can support stationary charging stations during increased load on the electrical grid, organize a temporary charging point in areas with limited electrical networks, and serve as an electricity source in emergency situations [3,4].

In existing studies, issues such as the placement and routing of mobile charging stations, the grouping of user demand by time, and the joint management of stationary and mobile charging are being extensively studied. Lee et al. developed a mixed integer linear programming model for managing mobile charging stations and used a genetic algorithm for large-scale problems [5]. Additionally, the 2025 studies accounted for the mobile device's need for recharging when optimizing both stationary and mobile chargers [6].

In this regard, the purpose of this study is to develop a functional architecture for a mobile battery charging station for electric vehicle maintenance and to substantiate its main technical parameters through engineering calculations.

Research methodology

The research methodology encompasses three interrelated areas: the analysis of scientific literature, the formation of a functional architecture for a mobile charging station, and the calculation of technical and energy parameters.

The literature review examined Scopus-indexed articles dedicated to mobile charging stations, research on energy storage systems, optimization work on charging stations, and communication standards between an electric vehicle and a charging device. The main focus was on the technical architecture of mobile charging, energy storage, charging capacity, dispatching, routing, and interaction with the power grid.

The following energy chain was adopted for the mobile charging station:

Power grid/renewable energy source - charging converter - stationary energy storage - MCS battery - DC/DC power module - DC charger - EV battery.

The mobile station's control architecture includes a battery management system (BMS), a charging protocol controller, a GPS/GNSS module, a telematics module, a central controller, and a user interface.

The DC charging section must comply with the requirements of the IEC 61851 series. IEC 61851-23:2023 covers input parameters up to 1000 V AC or 1500 V DC and output parameters up to 1500 V DC for DC EV supply equipment. IEC 61851-24:2023 defines the requirements for digital communication between the EV and the charging device during DC charging [7,8].

The ISO 15118 series is of great importance in organizing high-level communication between the vehicle and the charger. ISO 15118-20:2022 also provides for communication functions that support two-way energy transmission [9].

The main energy parameters of a mobile station are determined by the following expressions:

$$E_{use} = E_{nom} \bullet SOC_{\max} - SOC_{\min} \quad (1)$$

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where Euse is the energy available from the battery, kW·h; Enom is the nominal capacity of the battery, kWh; SOCmax and SOCmin are the upper and lower limits of the operating range.

Energy transferred to an electric vehicle:

$$E_{EV} = \frac{E_{use}}{\eta_c} \quad (2)$$

where η_c c is the total efficiency of the charging energy circuit.

The theoretical service capacity of a station is given by the energy supplied per service Es:

$$N_s = \frac{E_{EV}}{\bullet E_s} \quad (3)$$

is defined as.

Idealized charging time:

$$t_c = \frac{E_s}{P_c} \quad (4)$$

where Pc is the charging power.

In practice, the actual charging time will be greater than this formula, as the charging power in an electric vehicle battery may decrease as the SOC increases. Therefore, the calculated tc should be interpreted not as the maximum, but as the theoretical time at nominal power.

Design and functional architecture of a mobile charging station

An accumulator energy storage system with a nominal capacity of 120 kWh was adopted as the main element of the proposed station. The station's undercarriage may be based on a commercial vehicle chassis equipped with an electric or internal combustion engine.

The composition of the mobile station consists of the following functional blocks:

System	Main function
Traction part	Station delivery to point of demand
Battery	Storage of electricity
BMS	Monitor element voltage, current, temperature, and SOC
DC/DC Converter	Adjust battery voltage to charging system
DC Charging Module	Controlled DC power transmission to electric vehicle
Protection system	Protection against short circuits, overcurrent, overvoltage, and insulation damage
Thermal control	Maintain normal battery and power electronics temperatures
GPS/GNSS	Locate station
Telematic module	Data exchange with the central server
Central controller	Coordinate all subsystems
User Interface	Manage ordering, charging, and checkout

The fundamental advantage of a mobile station is that the energy source moves together with the transport. At a stationary station, the electric vehicle approaches the power source, while at a mobile station, the power source approaches the electric vehicle.

This feature is especially important in cases where the charge demand is unevenly distributed in space. For example, in the city center, in a large parking lot, near an airport or train station, in an area where a major event is taking place, or in the event of a temporary shutdown of a stationary station, the mobile station can be directed to the point of demand.

Technical accounting of the energy storage system

In the proposed concept, the nominal capacity of the accumulator is:

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$$E_{nom} = 120 \quad kWh$$

accepted as.

To extend the battery's service life and protect it from deep discharge, the SOC operating range was set at 15–90%. Then the energy that can be used is:

$$E_{use} = 120(0.90 - 0.15) = 90; \quad kWh$$

constitutes.

The theoretical energy that can be transferred to an electric vehicle when the total efficiency of power electronics, cables, and switching circuits is assumed to be 94%:

$$E_{EV} = \frac{90}{0.94} = 84.6; \quad kWh$$

will do.

If 40 kWh of energy is supplied to one electric vehicle during maintenance, the number of theoretical services is:

$$N_s = \frac{84.6}{40} = 2.115$$

equals.

Thus, in the proposed 120 kWh battery configuration, it is possible to partially or fully perform the second service after one full service with an energy requirement of 40 kWh. However, this result is an idealized energy calculation that does not take into account the driving energy of the vehicle, auxiliary device consumption, battery temperature, power drop during the charging process, and the station's safety reserves.

Therefore, in practice, the operator must set the minimum SOC limit of the station battery not only based on the technical minimum but also taking into account the driving energy required to travel to the next service.

DC charging power and charging time

The nominal power of the DC fast charging module at the mobile station was taken as 60 kW.

To transmit 40 kWh of energy at an ideal capacity of 60 kWh:

$$t_c = \frac{40}{60} = 0.667; \ h$$

or about 40 minutes.

For 50 kWh of energy:

$$t_c = \frac{50}{60} = 0.833; \ h$$

that is, it will take about 50 minutes.

These calculations are based on a simplified condition that the electric vehicle battery receives 60 kW of power throughout the entire process. During the actual charging process, the charging capacity may decrease as the battery's SOC level rises. Therefore, when charging to 80–100% SOC, the theoretical result for 40–50 minutes differs from the real-time result.

When choosing a 60 kW capacity for a mobile station, the primary goal is not the maximum charging speed, but to ensure a balance between energy storage, power electronics mass, heat release, battery discharge current, and the station's mobility capabilities.

Intelligent control and mobile station routing

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The efficiency of a mobile charging station is determined not only by battery capacity and charging capacity. It is also important which electric vehicle the station will be sent to, when, and along which route.

A charging order for a mobile station may contain the following information:

- geographical coordinates of the electric vehicle;
- the amount of energy required;
- minimum SOC;
- the time interval for which the service is accepted;
- vehicle charging standard;
- required charging capacity;
- user priority level.

The dispatching algorithm must jointly assess station locations, residual energy, mileage, travel time, charging requirements, and the occupancy of stationary stations.

The overall optimization goal can be conventionally expressed as the following function:

$$F = w_1 \bullet T + w_2 \bullet D + w_3 \bullet C + w_4 \bullet C + w_5 \bullet P \quad (5)$$

where: T is the user's waiting time; D is the distance traveled by the mobile station; C - energy consumption; C is the cost associated with battery degradation; P - unserved demand; wi - weighting coefficients of the target functions.

This approach corresponds to modern trends in literature. Lee et al. proposed an optimization model that combined mobile charging clustering, demand coverage, temporary charging locations, mobile station dispatching, and charging schedule [5]. Cui et al. have studied how to simultaneously optimize the routes of mobile chargers with different time intervals and service efficiency [10].

Integration of mobile and stationary charging stations

The most optimal application model for a mobile station is its use as an additional resource rather than a competitor to the stationary charging infrastructure.

When queues increase at stationary stations, the mobile station is sent to the area with the highest demand. When demand decreases, it returns to the depot or a special charging point to replenish the energy reserve.

In such an architecture, the charging network:

stationary stations + mobile charging stations + energy storage systems + central dispatch platform will have the form.

Research from 2025 indicates that the combined optimization of stationary and mobile charging systems must also account for the mobile station's recharging needs [6]. In a study published in 2026, the location and capacity of stationary stations, the number of mobile chargers, and their multi-cycle dispatching were optimized together. The study shows that the service life for a hybrid fixed-mobile circuit reaches 90.99% [11]. This result is a modeling result specific to the Xi'an region and cannot be directly transferred to other cities, but it shows that joint planning of mobile and stationary infrastructure is an effective direction.

Battery and thermal control in a mobile station

In a mobile charging station, the battery is exposed to two types of loads. The first is the transport energy associated with driving the station, and the second is the process of transferring electricity to charge an electric vehicle.

Therefore, the BMS for the station battery should not be limited solely to calculating the SOC. It must monitor cell voltage, current, temperature, maximum charging and discharging current, insulation status, and emergency situations.

The possibility of using lithium-iron-phosphate (LiFePO4) batteries for energy storage at mobile charging stations is also considered in the scientific literature. It has been shown that the

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combined use of a battery and a supercapacitor can improve current dynamics during high-power charging [12].

The importance of thermal control increases as the charging power increases. In a 60 kW charging module, a certain portion of electrical energy is converted into heat. For example, if the total efficiency of power electronics is 94%, then with an electrical power of 60 kW:

$$P = 60(1-0.94) = 3.6;\ kW$$

energy around appears as heat loss.

Therefore, the choice of air or liquid cooling system for the battery, DC/DC converter and charging module should be justified in accordance with the climatic conditions and operating modes of the station.

Communication and digital management

Along with the power unit, the intelligent mobile charging station will also have an information and communication system. The station transmits its coordinates to the central server via GPS, the BMS reports the battery status, and the charging controller coordinates power parameters with the electric vehicle.

The ISO 15118-20:2022 standard defines the communication between the electric vehicle and EVSE, including the necessary messages and processes for two-way energy transmission [9]. IEC 61851-24:2023 defines the digital control communication between EV and DC EVSE in DC charging [8].

Thus, the digital architecture of a mobile station can consist of the following levels:

BMS - charging controller - central controller - telematic module - cloud server - mobile application/dispatch platform.

In such an architecture, the user can send a charging request through the mobile application, see the estimated arrival time of the station, track the charging process, and make a payment.

Results

The basic mobile charging station configuration developed based on the research is characterized by the following parameters.

Parameter	Suggested value
Nominal energy of the accumulator	120 kWh
Operating SOC range	15–90%
Usable energy	90 kWh
Power circuit efficiency	94%
Theoretical energy transfer to an electric vehicle	84.6 kWh
DC Charging Power	60 kW
Ideal charging time for 40 kWh	40 minutes
Ideal charging time for 50 kWh	50 minutes
Theoretical number of services per 40 kWh	2.12
60 kW power loss	3.6 kW
Main control system	BMS + central controller
Geolocation	GPS/GNSS
DC Charging Communication	IEC 61851 series
High-level EV-EVSE communication	ISO 15118 series

Calculations show that a 120 kWh battery can be a reasonable configuration as a medium-capacity mobile station concept to power a 60 kW DC charging module. 90 kWh of operating energy is available in the 15–90% SOC range. With an energy efficiency of 94%, up to 84.6 kWh of energy can be transferred to an electric vehicle.

An important feature of this configuration is that the station's battery capacity and charging capacity are coordinated. A 60 kW battery generates a power ratio of around 0.5C compared to a

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rated battery of 120 kW·h. This value must be verified separately with specific battery chemistry and manufacturer data, so it cannot be accepted as a universal operational norm.

Мобил станциянинг хизмат кўрсатиш қобилиятини ошириш учун зарядлаш it is advisable to formulate requirements not only for a single vehicle, but also for a regional cluster. In cases where several electric vehicles are concentrated at a single point, the station can serve them at a temporary charging point instead of following them sequentially. In scientific literature, the formation of such temporary charging points and the grouping of requirements are considered a means of increasing the operational efficiency of mobile stations [5].

Discussion

The primary advantage of a mobile charging station is its spatial mobility. While the construction of a stationary station requires a permanent infrastructure at the point of demand, a mobile station can be redistributed in accordance with changes in demand.

However, mobility itself does not automatically provide economic efficiency. The mobile station has an expensive battery energy reserve, charging electronics, vehicle, thermal control, telematics, and maintenance costs. Therefore, its economic efficiency depends on the station utilization factor, the number of services per day, the travel distance, the cost of energy, and battery degradation.

The issue of routing mobile stations is also important. Cui et al. have shown the need to optimize the routes of stations with different service efficiency and time intervals in mobile charging services [10]. Li et al. argued for the need to jointly optimize the charging and recharging processes of mobile stations [5].

Another important issue is battery degradation. Since the mobile station battery operates in frequent charging and discharging cycles, its operating costs should not be assessed solely by the cost of electricity. In the optimal dispatching algorithm, the conditional value of battery degradation must be included in the target function.

Research from 2025 shows that the possibilities of integrating mobile charging stations with energy storage systems and using them to manage grid demand are expanding. Specifically, mobile energy storage devices can be used to support multiple parking or charging points [13].

Another study in 2025 developed a model for the joint management of mobile charging stations and collective energy storage systems, and the modeling yielded results in reducing standby time at stationary charging stations to zero and reducing emissions by up to 90%. However, these indicators belong to a specific modeling scenario, and it would be incorrect to interpret them as a universal operational result [14,15].

Therefore, in future research, it is advisable to develop a model for a mobile charging station that combines real traffic data, SOC profiles of electric vehicles, electricity tariffs, station travel costs, and battery degradation.

Conclusion

The research results show that a mobile charging station for electric vehicles is a promising technology that complements stationary charging infrastructure. Its main advantage is the ability to dynamically move the charging service to where demand arises.

In the developed conceptual model, a 120 kWh rated battery, a 15-90% SOC operating range, and a 60 kWh DC charging module were adopted. According to calculations, the usable energy of the battery is 90 kWh, and the energy that can be transferred to the electric vehicle at a total energy efficiency of 94% is 84.6 kWh. For a 40 kWh charging service, the ideal time at a rated capacity of 60 kW is 40 minutes. In real-world operation, this time may increase due to battery charging characteristics, power drops, thermal mode, and auxiliary consumers.

To improve the technical efficiency of a mobile station, the battery capacity, DC charging capacity, range, SOC reserve, and thermal control must be designed in an interconnected manner.

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It is also advisable to manage the station not only as a "mobile charger" but also as a mobile energy storage and charging resource.

The most important scientific result is the concept of combining mobile and stationary charging infrastructure into a single intelligent system. In such a system, the selection and routing of a mobile station are carried out based on user demand, the station's remaining energy, travel distance, charging capacity, stationary station occupancy, and battery degradation.

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