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Smart EV Charging Slot Booking & Load Balancer

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Abstract: *The rapid growth of electric vehicles (EVs) is placing two kinds of pressure on public charging stations: drivers cannot be sure that a charger will be free when they arrive, and many simultaneous sessions can push the station's demand beyond the capacity of its grid connection. This paper presents the design of a Smart EV Charging Slot Booking and Load Balancer system that addresses both problems together. Drivers reserve a charger and a time slot through a web or mobile application; a booking engine admits a request only if a charger is free and enough power budget remains in every slot of the reservation; and a dynamic load balancer shares the site's power limit among the vehicles that are charging at any moment. The paper describes the architecture, the booking and balancing algorithms, the technology stack and the supported features. The core scheduling and balancing logic is evaluated in a Python simulation of an eight-charger station over 100 randomly generated days, comparing uncontrolled first-come-first-served charging, load balancing alone, and booking with load balancing. With a site limit of 80 kW, uncontrolled charging exceeded the limit for 15.1% of the day, with a mean daily peak of 102 kW, whereas both controlled schemes never exceeded it. Booking removed on-site queuing but rejected more requests than the balancer alone, a trade-off that is analysed in the paper. The results come from simulated, not field, data and are intended to guide the design of the real system.*

Keywords: Electric Vehicle, Charging Station, Slot Booking, Load Balancing, Smart Charging, Demand Management, OCPP, Simulation

1. INTRODUCTION

Transport electrification is accelerating worldwide. The International Energy Agency reports that electric car sales have grown from a few hundred thousand a year in the mid-2010s to well over ten million a year, and India has set out national guidelines to encourage public charging infrastructure .As the number of EVs grows, public charging stations become shared resources, and two practical problems appear.

The first is a problem for the driver. A charging session lasts from tens of minutes to several hours, so a station with a handful of chargers is easily fully occupied. A driver who reaches a station with all chargers busy must wait, travel to another station or give up, and has no way of knowing this in advance. The second is a problem for the operator and the grid. A station is connected to the grid through a transformer and a supply contract that allow only a limited power draw. If many vehicles start charging at full power at the same time, the demand can exceed this limit, which risks overloaded equipment, tripped breakers and penalty charges for peak demand.

This paper proposes a Smart EV Charging Slot Booking and Load Balancer system that treats both problems together. A booking engine lets drivers reserve a charger and a time slot and admits a booking only when the station can actually supply it. A dynamic load balancer then divides the available power among the vehicles that are plugged in so that the site limit is never exceeded. The contributions of this work are:

- a modular architecture that combines slot reservation, dynamic load balancing and charger communication through the Open Charge Point Protocol (OCPP)

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- a power-aware booking algorithm that checks charger availability and the remaining power budget of every time slot before confirming a reservation;
- a water-filling load-balancing rule that honours each reservation and shares unused power among active vehicles; and
- a simulation study that compares uncontrolled charging, load balancing alone and booking with load balancing, including the trade-offs that booking introduces.

The rest of the paper is organised as follows. Section II reviews related work. Section III states the problem and objectives. Section IV describes the architecture and algorithms. Section V lists the technology stack and Section VI the features. Section VII presents the simulation study. Sections VIII to X cover applications, advantages and limitations, and future scope, and Section XI concludes the paper.

II. LITERATURE REVIEW

The effect of uncoordinated EV charging on power networks has been studied for more than a decade. Clement-Nyns et al. showed that when plug-in vehicles charge in an uncoordinated way on a residential feeder, power losses and voltage deviations increase, and that coordinated charging reduces them Lopes et al. and Richardson reviewed how EVs can be integrated into the power system and concluded that controlling when and how fast vehicles charge is the key to avoiding network reinforcement [

Many scheduling methods have been proposed. Mukherjee and Gupta surveyed charge-scheduling approaches for the smart grid, grouping them by objective (cost, load levelling, loss reduction) and by whether control is centralised or distributed. Gan et al. proposed a decentralised protocol in which vehicles iteratively respond to a price signal and converge to a valley-filling schedule. Sortomme and El-Sharkawi studied optimal charging strategies for aggregators that must also consider regulation services. Lee et al. described the Adaptive Charging Network (ACN), a deployed system in which charger power is scheduled online against a shared capacity limit, and released a public dataset of real charging sessions. This line of work shows that limiting aggregate power while still meeting driver energy demands is practical.

Most of the studies above concentrate on optimisation or on the grid side, and they usually assume that vehicles are already present. Fewer works describe a complete, student-implementable system that joins a driver-facing reservation service with a station-level power limit. The present paper aims to fill this gap with a simple, transparent design, in which every decision rule can be explained to drivers and operators.

III. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

Public chargers are commonly used on a first-come-first-served basis. Drivers cannot reserve a charger, queues form at peak hours, and the station has no mechanism to keep its total demand below the grid connection limit. A station that is dimensioned for the worst case would be expensive, whereas a station that is dimensioned for the average case risks overload and disappointed drivers.

B. Objectives

- To let EV drivers search stations and book a charger for a chosen time slot.
- To admit a booking only if a free charger and sufficient power are available for the whole reservation.
- To keep the total power drawn by the station at or below a configurable site limit at all times.
- To share power among active sessions fairly and to finish each session in the time that was reserved.

IV. SYSTEM ARCHITECTURE AND METHODOLOGY

A. Overall Architecture

The proposed system follows a client–server design, as shown in Fig. Drivers use a mobile or web application and the station operator uses an administration dashboard. Both talk to a cloud backend through a REST API. The backend contains five modules: an authentication and user service, a slot booking engine, a station and charger registry, a dynamic

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load balancer and a database. The backend communicates with the station controller through OCPP. The controller applies the power limits computed by the balancer to individual chargers and returns meter readings and the site grid limit.

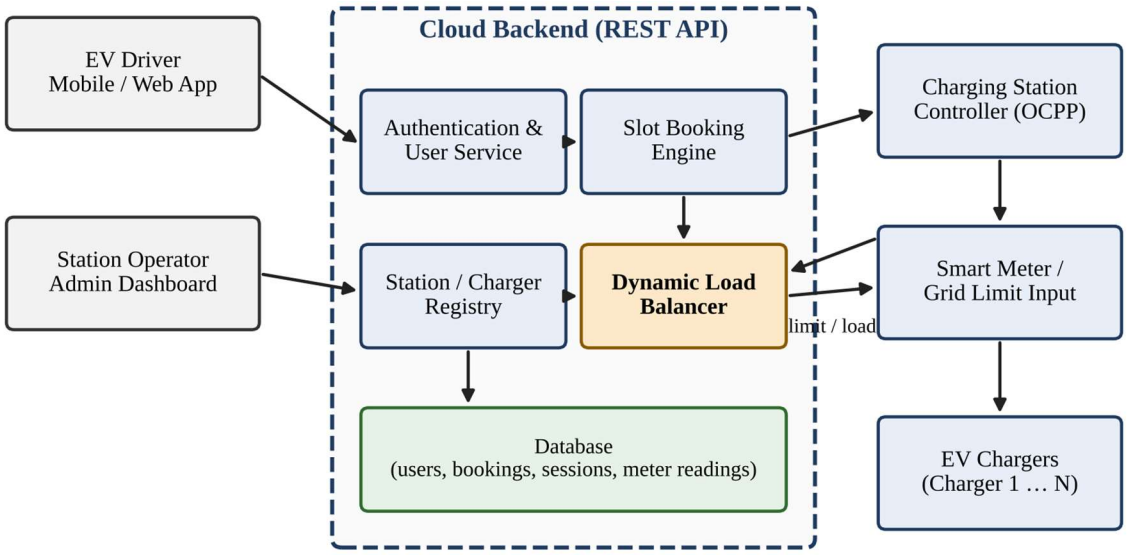


Fig. 1. Architecture of the Smart EV Charging Slot Booking and Load Balancer system

B. Functional Modules

- User service: registration, login, vehicle profile (battery capacity, maximum charging power) and booking history.
- Station and charger registry: location, number of chargers, connector type, rated power and the site power limit configured by the operator.
- Slot booking engine: accepts a request, searches for a feasible slot and charger and stores the reservation.
- Dynamic load balancer: runs at a fixed interval (five minutes in the simulation) and computes the power allocated to each active session.
- Database: users, stations, bookings, sessions and meter readings, which also provide data for reports.

C. Slot Booking Algorithm

A booking request contains the energy E the driver wants (in kWh), the maximum power pmax that the vehicle accepts and the preferred start time. Time is divided into 15-minute slots. The booking engine keeps, for every slot, the remaining power budget (site limit minus the power already reserved) and, for every charger, the slots in which it is reserved. The procedure, summarised in Fig. 2, is:

- Take the candidate start slots in order from the preferred start up to a tolerance of 60 minutes later.
- For each candidate start, try the power levels 22, 11, 7.4 and 3.7 kW that do not exceed pmax, from the highest downwards. For a level p, the reservation length is the time needed to deliver E at p, rounded up to whole slots.
- Accept the first combination for which some charger is free for the whole length and the remaining power budget is at least p in every slot of the reservation. Choose, among the free chargers, the one that has been idle for the shortest time before the start (best fit), which reduces fragmentation of the timetable.
- Subtract p from the budget of every reserved slot. If no combination works, reject the request immediately so that the driver can look elsewhere.

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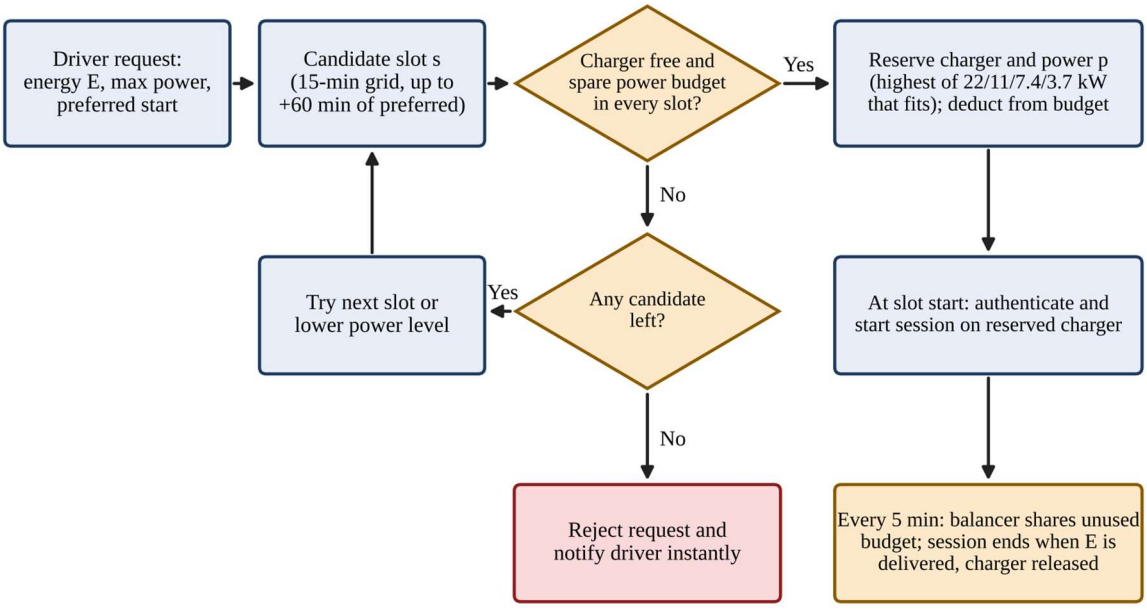


Fig. 2. Slot booking and load balancing flow

D. Dynamic Load Balancing

Because each reservation consumes only its own reserved power, the sum of reserved power in any slot never exceeds the site limit L. The load balancer then runs at every control interval. Let A be the set of active sessions, ri the reserved power of session i and ci the largest power that session can still use, which is the smaller of the vehicle limit and the power needed to deliver its remaining energy in one interval. The balancer works in two steps:

- Guaranteed share: every active session receives min(ri, ci).
- Water-filling of spare power: the unused part of L is split equally among the sessions that can still accept more power, and any surplus above a session's ci is passed to the others. The step repeats until the spare power is used up or no session can take more. This is the classical max–min fair sharing rule.

A session that receives extra power finishes before its reserved end and frees its charger, although later reservations on that charger still start at their booked time. The same balancer can be used without bookings: when drivers simply plug in, each active session gets an equal water-filling share of L, and a vehicle's charging time is lengthened when the station is busy. This variant is called "load balancer only" in Section VII.

E. Data Model and Interfaces

The database holds five main entities: User, Vehicle, Station/Charger, Booking (user, charger, start, end, reserved power, energy, status) and Session (actual start and end, energy delivered, meter log). The REST API exposes endpoints to search stations, to create, view and cancel bookings, to start and stop sessions, and to read station reports. Between the backend and the station, OCPP charging-profile messages carry the power limit for each charger and meter values flow back for monitoring.

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V. TECHNOLOGY STACK

The system is built with widely available, mostly open-source components, summarised in Table I.

TABLE I: TECHNOLOGIES USED IN THE PROPOSED SYSTEM

Component	Technology	Purpose
Client application	Web / mobile app (HTML, CSS, JavaScript)	Search, booking and session status for drivers
Admin dashboard	Web application	Station set-up, limits and reports for operators
Backend	Python with a REST framework	Booking engine, load balancer, user service
Database	Relational database (MySQL / PostgreSQL)	Users, bookings, sessions, meter data
Charger communication	OCPP over WebSocket	Charging-profile limits and meter values
Simulation and analysis	Python, NumPy, Matplotlib	Evaluation of scheduling and balancing logic

VI. FEATURES AND SUPPORTED OPERATIONS

The main features and the way they are used are listed in Table II.

TABLE II: KEY FEATURES OF THE SYSTEM

Feature	Description	Example use
Station search	Lists stations with free chargers and connector types	"Find CCS chargers near me"
Slot booking	Reserves a charger and power for a time slot	Book 30 kWh from 6 PM
Instant rejection	Tells the driver at once if no feasible slot exists	Choose another time or station
Dynamic load balancing	Keeps total station power under the site limit	Peak evening hours
Session monitoring	Shows power, energy and remaining time	Live status in the app
Operator reports	Utilisation, energy delivered and peak load	Daily and monthly planning
Configurable limit	Operator sets the site limit and power levels	Adapt to a new transformer

VII. SIMULATION STUDY

A. Setup

To study the behaviour of the booking and balancing logic, a Python simulation of one station was written. It advances time in five-minute steps over a 24-hour day. The parameters are given in Table III. They are assumptions chosen to represent a mid-sized urban public station and are not measurements from a real site. Demand is generated with two peaks, one around 9 AM and one around 6:30 PM, plus a small uniform background. Three schemes are compared on identical sets of arrivals.

- Uncontrolled (FCFS): a vehicle takes a free charger on arrival and charges at its full power. If all chargers are busy it queues and leaves after 60 minutes.
- Load balancer only: same first-come-first-served arrival process, but the site limit is shared by water-filling among active sessions.
- Booking + load balancer: the proposed scheme of Section IV, with a 60-minute tolerance on the start time.

TABLE III: SIMULATION PARAMETERS

Parameter	Value
Chargers	8
Vehicle maximum power	7.4 kW (40%), 11 kW (40%), 22 kW (20%)
Requests per day	60, arrival peaks near 9 AM and 6:30 PM

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Energy per request	Uniform, 8 to 35 kWh (mean demand about 1300 kWh/day)
Driver tolerance	60 minutes of waiting or start-time shift
Slot length / control interval	15 minutes / 5 minutes
Site limit	40, 60, 80, 100, 120 kW
Repetitions	100 random days (seeds 0 to 99), same days for all schemes

B. Results

TABLE IV: SIMULATION RESULTS AT 80 KW (MEAN ± STD. DEV. OVER 100 DAYS)

Metric (80 kW limit)	Uncontrolled	Balancer only	Booking + balancer
Peak load (kW)	102 ± 9	80 ± 0	80 ± 0
Time above limit (%)	15.1 ± 6.6	0.0 ± 0.0	0.0 ± 0.0
Requests not served (%)	23.1 ± 6.3	24.6 ± 5.6	32.5 ± 5.4
Delay of start vs. preferred (min)	19.6 ± 3.3	20.1 ± 3.1	22.1 ± 3.1
Time spent queuing on site (min/vehicle)	28.9 ± 4.0	29.9 ± 3.6	0.0 ± 0.0
Energy delivered (kWh/day)	979 ± 73	958 ± 59	853 ± 59
Load factor (mean/peak)	0.40 ± 0.04	0.50 ± 0.03	0.44 ± 0.03

Table IV shows the results for an 80 kW limit. Uncontrolled charging reached a mean daily peak of 102 kW, about 27% above the limit, and spent 15.1% of the day above it. Both controlled schemes held the load at or below 80 kW in every simulated day, by construction of the balancer. Fig. 3 illustrates a single simulated day: the uncontrolled load rises to nearly 100 kW in the morning and evening peaks, whereas the controlled schemes are capped at the limit.

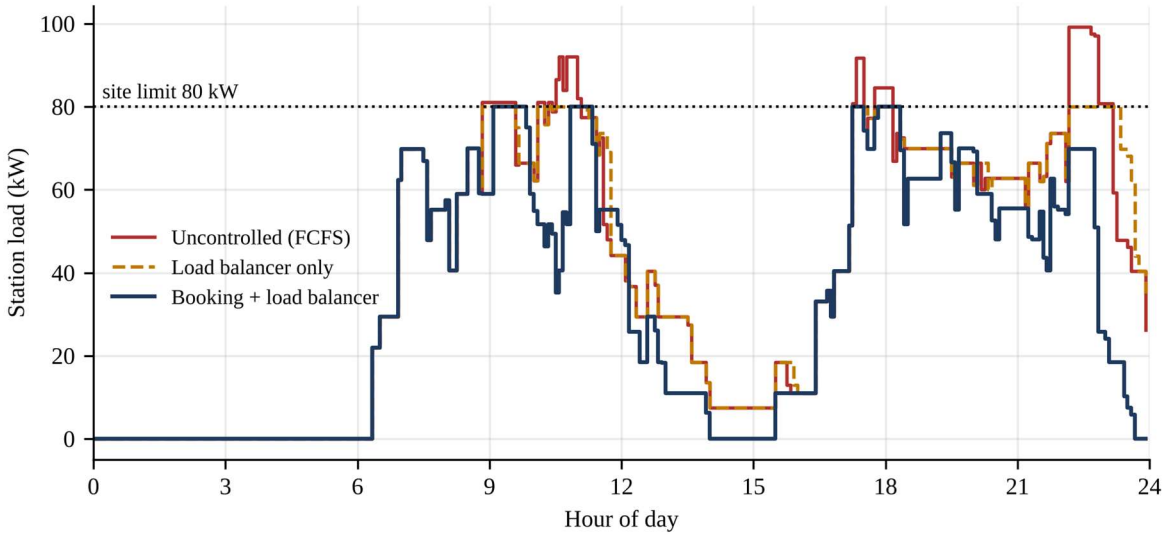


Fig. 3. Station load over one simulated day (limit 80 kW)

The price of the cap depends on how tight it is. Fig. 4 shows that uncontrolled charging exceeded the limit for 51% of the day at 40 kW, 39% at 60 kW, 15% at 80 kW and 1.4% at 100 kW. Under the controlled schemes the share of unserved requests rises as the limit falls. At 80 kW the balancer alone served almost as many requests as the uncontrolled station (24.6% unserved against 23.1%), but at 60 kW it left 33% unserved because vehicles were slowed and kept chargers occupied for longer.

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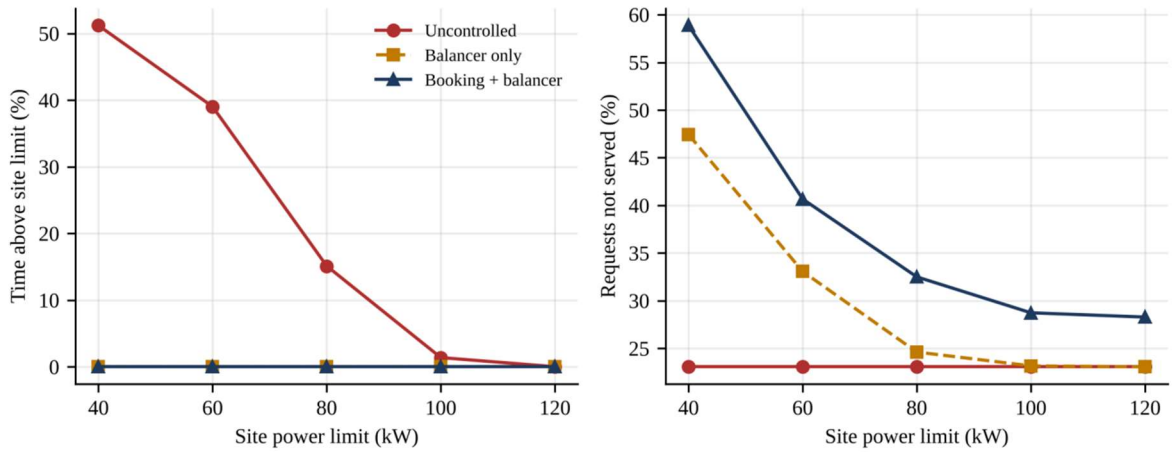


Fig. 4. Effect of the site power limit on overload time (left) and unserved requests (right)

C. Discussion

Booking removed on-site queuing: a driver whose request is accepted arrives at the booked start, while in the other two schemes the mean vehicle spent about 29 minutes queuing, including the 60 minutes of drivers who finally left unserved. This difference follows from how the booking scheme is defined, and it is the benefit that drivers would notice most. However, booking also rejected more requests than the balancer alone (32.5% against 24.6% at 80 kW) and delivered less energy per day (853 kWh against 958 kWh). Two design choices cause this: a reservation fixes a charger and a power level for its whole duration, which fragments the timetable, and the slot grid of 15 minutes rounds each reservation up. In the real system the rejected drivers are informed at once and can choose another time, which is less costly than waiting at the station, but the operator should be aware of the lost throughput.

D. Threats to Validity

The simulation uses synthetic demand and a simplified charging model. Real vehicles reduce their power as the battery fills, drivers do not always arrive on time, and bookings are often made hours or days ahead, not at arrival. The 100-day repetition removes random variation between days but not these modelling assumptions. The numbers in this paper must not be taken as predictions for a specific station.

VIII. APPLICATIONS

- Public charging stations on highways, in malls and in cities.
- Residential societies and apartment complexes with shared transformers.
- Office campuses and educational campuses with workplace charging.

IX. ADVANTAGES AND LIMITATIONS

A. Advantages

- Guaranteed charger and time slot for accepted bookings.
- Site power limit never exceeded, which protects equipment and avoids peak-demand penalties.
- Simple, explainable rules that operators can configure without optimisation software.

B. Limitations

- Evaluation so far is by simulation with assumed parameters, not by field trials.
- Fixed reservations lower throughput compared with the balancer alone when the limit is tight.
- No-shows and overstays are not modelled and would waste reserved capacity.

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X. FUTURE SCOPE

- Field validation: deploy at a campus station and compare measured results with the simulation.
- Smarter reservations: release unused reserved time, allow cancellation penalties and overbooking limits for no-shows.
- Time-of-use pricing: use dynamic tariffs to move flexible demand to off-peak slots.
- Renewables and storage: include solar output and battery storage in the site budget.
- Prediction: forecast demand from historical sessions, for example from public datasets.
- Vehicle-to-grid: extend the balancer with discharge for grid support.
- Payments and security: secure payment integration and authenticated charger communication.

TABLE V: PROPOSED ROADMAP OF ENHANCEMENTS

Phase	Enhancement	Expected benefit
1	Prototype and campus field trial	Real data on arrivals and no-shows
2	Reservation release and alternative slots	Lower rejection rate
3	Tariff-aware scheduling	Cost saving and flatter load
4	Solar, storage and V2G integration	Greater site capacity and resilience

XI. CONCLUSION

This paper presented a Smart EV Charging Slot Booking and Load Balancer system that lets drivers reserve a charger and keeps the total power of a charging station within its grid limit. A power-aware booking algorithm confirms a reservation only when both a charger and the required power are available, and a water-filling load balancer shares power among active sessions. In a simulation of an eight-charger station, uncontrolled charging exceeded an 80 kW limit for about 15% of the day, while the proposed controls never did. Booking eliminated on-site queuing at the cost of a higher rejection rate, and the balancer alone gave the best throughput under the cap. These findings show both the promise and the trade-offs of the design.

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REFERENCES

1. International Energy Agency, "Global EV Outlook 2024: Moving towards increased affordability," IEA, Paris, France, 2024.
2. Ministry of Power, Government of India, "Revised guidelines and specifications for charging infrastructure for electric vehicles," New Delhi, India, 2022.
3. K. Clement-Nyns, E. Haesen, and J. Driesen, "The impact of charging plug-in hybrid electric vehicles on a residential distribution grid," IEEE Trans. Power Syst., vol. 25, no. 1, pp. 371–380, Feb. 2010.
4. N. Mukherjee and R. Gupta, "A review of charge scheduling of electric vehicles in smart grid," IEEE Syst. J., vol. 9, no. 4, pp. 1541–1553, Dec. 2015.
5. Z. J. Lee, T. Li, and S. H. Low, "ACN-Data: Analysis and applications of an open EV charging dataset," in Proc. ACM e-Energy, 2019, pp. 139–149.
6. Open Charge Alliance, "Open Charge Point Protocol (OCPP) specification." [Online]. Available: https://openchargealliance.org/
7. L. Gan, U. Topcu, and S. H. Low, "Optimal decentralized protocol for electric vehicle charging," IEEE Trans. Power Syst., vol. 28, no. 2, pp. 940–951, May 2013.
8. D. B. Richardson, "Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration," Renew. Sustain. Energy Rev., vol. 19, pp. 247–254, 2013.