EV CHARGE SHOW

# EV Charge Show 2025 Conference
# Abstracts

[Abstract:0002] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Development of a Modular, Native EVSE Control System to Overcome Imported PLC Card Limitations for Reliable, Standard-Compliant Fast Charging

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In the commercialization phase of our modular Electric Vehicle Supply Equipment (EVSE) project, we identified key barriers rooted in the limitations of conventional monoblock devices and imported charge-control modules. Monoblock units, due to their bulky volume and weight, lack the capacity for flexible power scaling to meet diverse customer requirements. In contrast, our modular architecture—with easily swappable, maintenance-friendly power modules—enables easy capacity expansion and the creation of variant product offerings. Initial field tests of our modular EVSE prototypes revealed hardware and software malfunctions originating from the charge controller card supplied by a third-party foreign manufacturer. The non-isolated design of this imported card rendered it susceptible to power-side electromagnetic noise, causing intermittent charge interruptions. Furthermore, the card's PLC-based vehicle communication interface could not tolerate transient errors and failed to satisfy ISO 15118 timing and SLAC handshake requirements, preventing charge initiation on some vehicles. Critically, its closed-source firmware and inadequate and lagging after-sales support precluded timely bug fixes or protocol optimizations. Comparable issues documented in user forums and social media indicate that these failures are widespread across similar third-party modules.

Following the successful completion of our R&D program, Aspower redesigned its EVSE systems by developing a fully indigenous charge controller card along with embedded, standards-compliant firmware. As illustrated in Figure 1, Aspower EVSE charge controller card is designed to provide communication between EV and EVSE via Power Line Communication (PLC) through all phases of charging operation. In addition to this main task, it can also measure the temperature of CCS2 gun and the DC leakage current. It supports ISO/IEC15118, DIN 70121 CAN, RS485, 10/100 Mbps Ethernet, USB 2.0 communication interfaces and protocols. The card includes MYC-Y6ULX-V2 as the CPU module with NXP i.MX 6UL/6ULL ARM Cortex-A7 processor. Operating System used is Linux 5.4.3. PLC interface is HomePlugGreenPHY, PLC module is RED-BEET-E 1.1, PLC chip is QCA7005. It has UART used as for the debug interface. The operating voltage is between 7VDC – 28VDC.

Figure 2 highlights the components removed from the original EVSE design, shown in pink. In our revised architecture, these parts are omitted, allowing us to swap the imported legacy charge card for our proprietary controller card (see Figure 1). This hardware-software co-design enabled robust PLC communication, compliance with ISO 15118 timing requirements, and reliable completion of SLAC procedures across all tested vehicle models. By reducing component count and system complexity, the solution achieved lower production costs and increased system reliability. Additionally, the adoption of an open and proprietary software architecture allowed for rapid troubleshooting and adaptability to evolving standards, overcoming the limitations posed by previously used closed-source platforms.

As a result, Aspower successfully transformed its EVSE product line into a commercially viable, nationally sovereign system that aligns with European Green Deal objectives for sustainable and intelligent transportation infrastructure. The enhanced EVSE systems delivered uninterrupted, high-efficiency charging with improved resilience and maintainability. Real-time remote monitoring and operational control were enabled through IoT-cloud integration, contributing to reduced operational downtime and minimized maintenance costs. This, in turn, enhanced the overall service quality for end users and improved profitability for charge point operators.

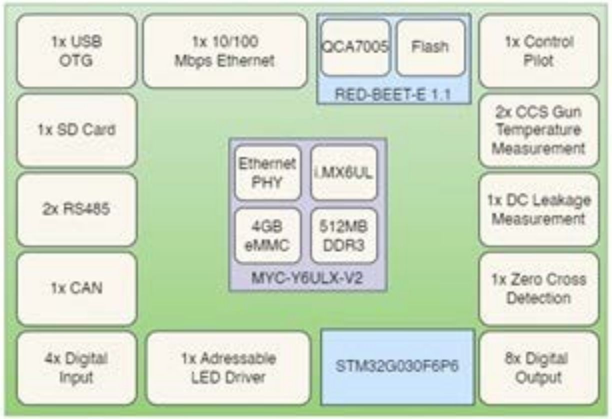
Through the resolution of SLAC issues, the charging process was reliably initiated and EVSE units operated with increased stability. This contributed significantly to user satisfaction and reinforced the company's reputation in both domestic and international markets. The integration of our control card enabled unified system control, allowing the elimination of redundant components—reducing manufacturing costs and providing a distinct competitive advantage. By delivering better service to customers while optimizing cost efficiency, the solution increased company profitability and growth potential. Field data from operational Aspower EVSE units, both domestically and abroad, demonstrated a charging success rate of 95% and above, validating the robustness and reliability of the developed solution.

Ultimately, our work contributes to accelerating the adoption of zero emission transport and deeper integration of renewables, fostering a resilient and sustainable mobility ecosystem aligned with international climate targets.

Acknowledgement
We acknowledge that this work is supported by the TÜBİTAK-TEYDEB Support Program (TÜBİTAK 1832, Project No: 3248194).

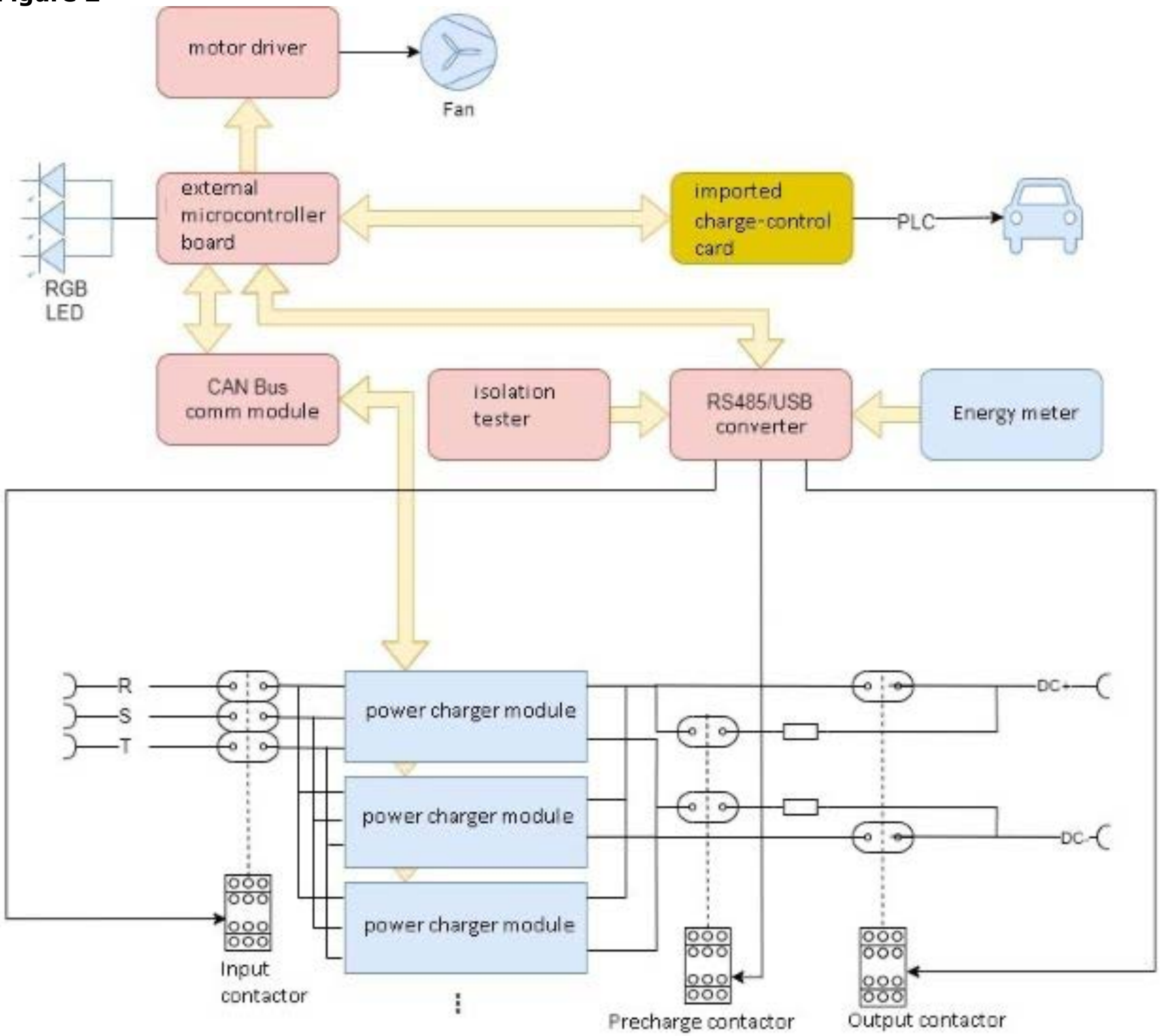
**Keywords:** Fast DC charging, charge control card, PLC, EVSE, EVC

**Figure 1**




*Aspower EVSE charge controller card.*

**Figure 2**




*Old EVSE design with the imported legacy charge controller. Pink blocks indicate the components omitted in our new design*

[Abstract:0003] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# EV Charging with Integrated Energy Storage

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The rapid electrification of transportation has escalated demand on power systems worldwide, often outpacing grid reinforcement. Battery-supported electric vehicle charging (EVC) systems—integrating on-site energy storage, bidirectional power electronics, and advanced energy management—offer a remedial pathway for areas with insufficient or unstable grid infrastructure. Beyond enabling reliable charging, these platforms serve as real-time grid monitors and active stability agents. By leveraging Vehicle-to-Grid (V2G) capabilities and supporting fleet operators, they create opportunities for government and private institutions to enhance grid observability and balance supply-demand dynamics. This paper provides a high-level overview of the core architecture and operating principles of next-generation EVC platforms, explores operational modes (e.g., peak shaving, arbitrage, PV optimization), analyzes their role in system-wide frequency regulation ("synthetic inertia"), and evaluates market and regulatory developments, including pilot integration of BESS into Türkiye's ancillary services framework.

Grid Stability, Inertia, and Monitoring:
Alternating-current networks nominally operate at 50 Hz; real-time balance of generation and load determines instantaneous frequency. When demand exceeds supply, frequency falls; conversely, when generation exceeds demand, it rises. If frequency breaches thresholds (e.g., drops below 49.8 Hz), protective relays trigger load shedding or generator trips to protect equipment and prevent cascading failures [1, 2]. Traditional synchronous generators furnish mechanical inertia, slowing frequency excursions, whereas inverter-based renewables lack this inherent inertia, leading to faster, deeper frequency swings. Advanced Battery Energy Storage Systems (BESS), reacting within milliseconds, can emulate "synthetic inertia" by instantaneously injecting or absorbing power to arrest frequency deviations. In parallel, inverter controls continuously measure grid parameters, making battery-supported EVCs effective distributed monitoring nodes for grid operators.

High-Level System Overview:
On the hardware front (see Figure 1), the system integrates several high-efficiency converters. The AC/DC bidirectional converter interfaces with the grid, enabling both charging and grid feed-in as needed. DC/DC MPPT converters manage solar inputs, extracting maximum power and conditioning it for either battery charging or direct EV support. The V2G DC/DC converter supports CCS2-compatible bidirectional charging, enabling flexible energy exchange between the EV, the on-site storage system, and the grid, depending on availability and system requirements. The battery pack acts as the buffer and arbitrage agent in the system. Capacity and configuration are modular and can be adjusted per deployment. This hardware backbone ensures compatibility with a range of renewable sources, EV types, and grid interaction profiles.

As for the software architecture, the core intelligence of the system lies in the EMS—the Energy Management System (see Figure 2). It optimizes the energy flow between components, adapting dynamically to local load demand, renewable generation, and electricity tariffs. Using predictive algorithms and real-time data, the EMS selects the most cost-effective and grid-friendly operation mode. Remote diagnostics via cloud-based monitoring allow for proactive maintenance, reducing downtime. A user-friendly interface gives operators visibility over system status, alerts, and optimization metrics (see Figure 3). This software-hardware synergy enables not just stability, but economic performance and grid resilience. Operating modes are dynamically managed based on the battery state-of-charge (SoC). For instance, during peak hours, peak shaving is prioritized—discharging batteries to reduce grid

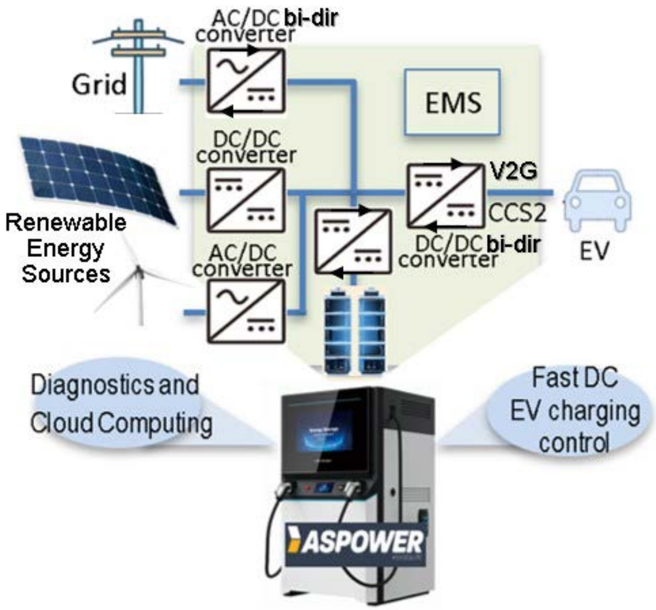
draw. At other times, the system may enter arbitrage mode—charging when prices are low and discharging when prices are high, particularly relevant under multiple-tariff structure. For renewable-heavy sites, PV optimization becomes the key—charging the battery during solar generation and discharging during grid peaks. The EMS algorithmically prioritizes these modes depending on SoC thresholds and forecast inputs.

Effects on Grid Stability & Monitoring:
By uniting monitoring and control, battery-integrated EVCs serve dual roles: they act as distributed phasor measurement units—reporting high-resolution grid data—and as active balancing agents—mitigating fluctuations through smart dispatch. V2G-enabled fleets can be enrolled under ancillary-service contracts, providing predictable capacity reserves. Government and corporate EV fleet operators can thereby transform their assets into distributed virtual power plants (VPP), enhancing both situational awareness and system resilience.

Acknowledgement
We acknowledge that part of this work is supported by the TÜBİTAK-TEYDEB Support Program TÜBİTAK 1507, Project No: 7240959.

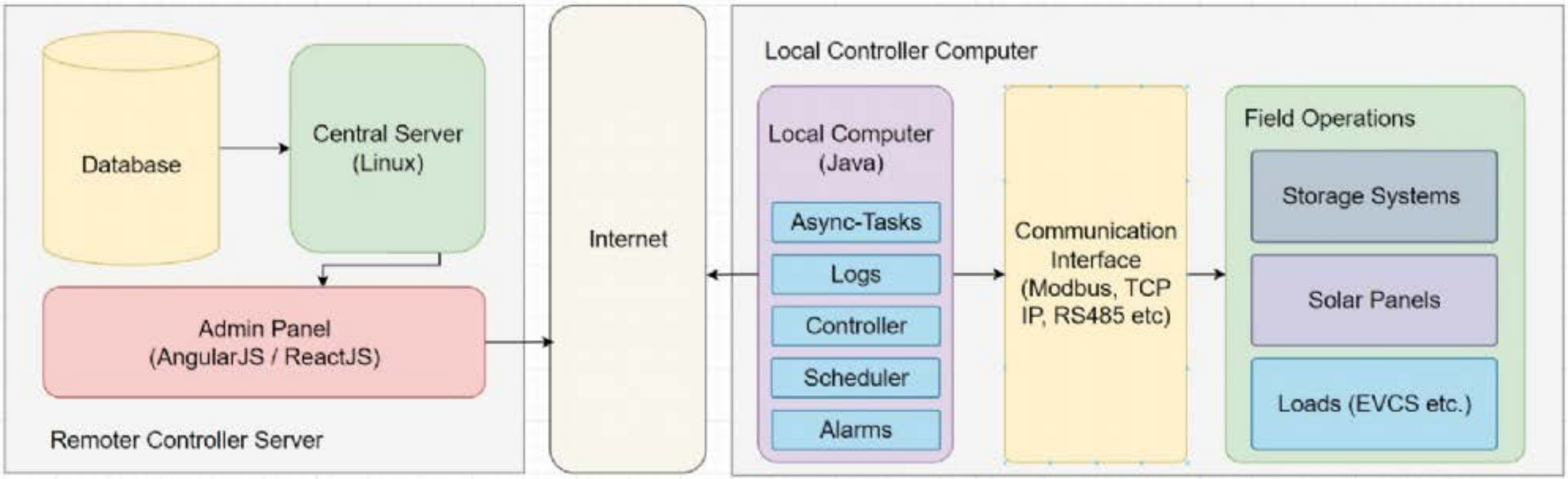
**Keywords:** Electric Vehicle Charging, Battery Energy Storage, Energy Management System, Vehicle-to-Grid, Grid Monitoring

**Figure 1**



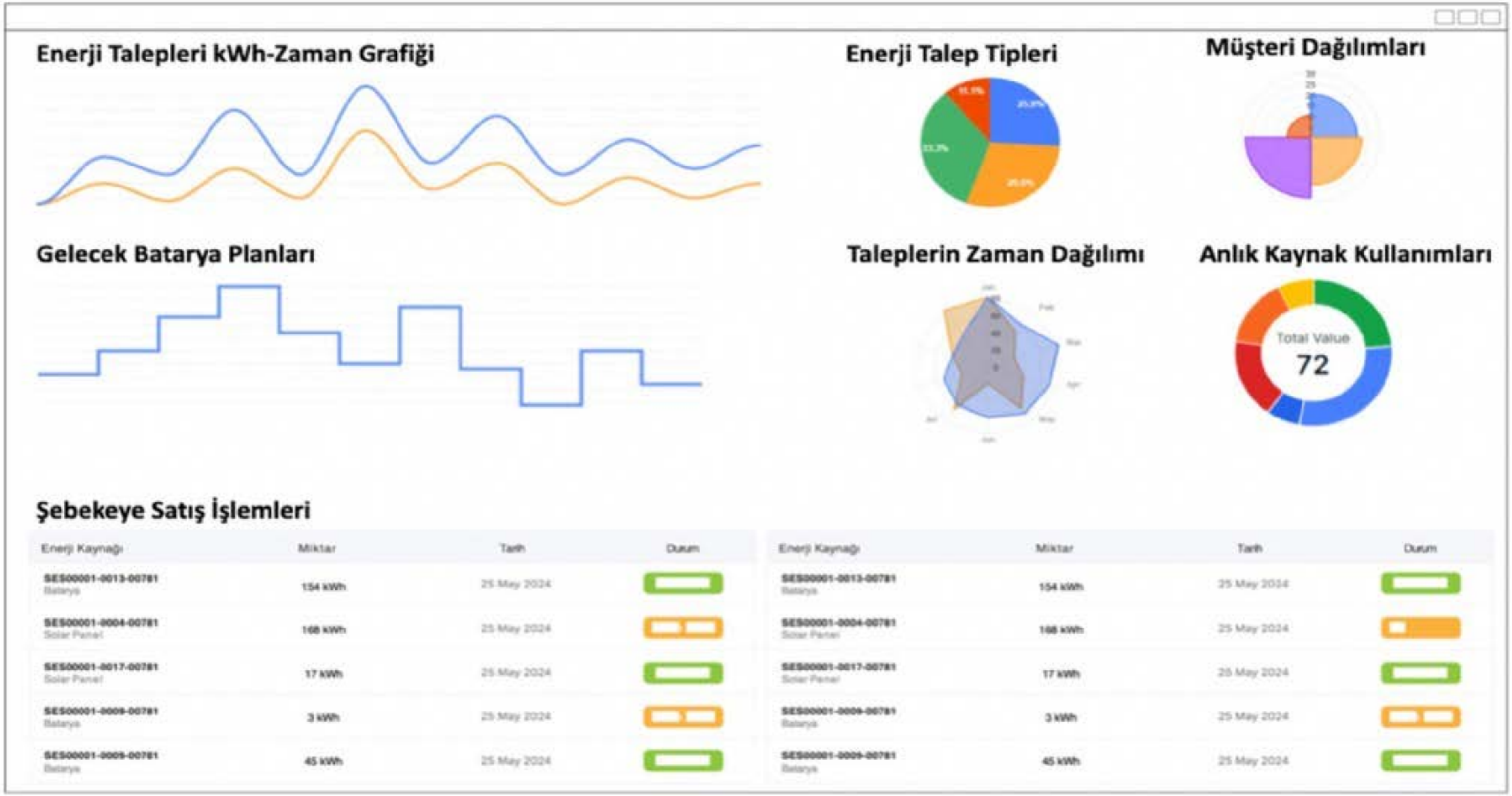

*Hardware Components*

**Figure 2**




*EMS Specifications: Linux –based server, Controller managing system decisions, Alarm mechanisms Multi-threaded operation, Communication interfaces*

**Figure 3**




*Example User Interface*

[Abstract:0006] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# The Numerical Modelling TMS of EVC

Şule Uysal
Vestel

The electric vehicle charging(EVC) station has been becoming crucial with the becoming widespread of electric vehicle(EV) in recent years. The demand of the quick charging of EV is addressing EVC to operate in high current and high power. High current and high power cause to overheat the electrical components ang generate the heat in the system. This waste heat should be threw away from the system. The CFD analysis of the each 40kW power module, used in DC EVC station produced by Vestel and that convert the AC current from the grid to the DC current, amplify to the desired power value and consist of 2 PCB that is ACDC-DCDC, has performed as using fans that have different CFM values in steady state approach using FVM. In the related CFD analysis of the power module, the critical component temperature and energy and momentum equations from air velocity and air temperature in module inlet and module outlet and the Nusselt correlations has been examinating. By forming different arrangements in the direction of the obtained findings, it is possible to increase the efficiency of the thermal control system depends on fans.

**Keywords:** Air Cooling,EVC Systems, Power Module,Thermal Management

[Abstract:0007] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# EVCify, OpEx AI

Ferhat Bal
EVCify Teknoloji A.Ş.

Shaping the Future with Operational Intelligence
Value Proposition:
“OpEx AI lays the foundation for operational excellence by fully digitalizing field service operations end-to-end.”

By integrating cutting-edge technologies such as Artificial Intelligence, Digital Twins, Predictive Analytics, IoT integration, and self-learning algorithms, OpEx AI predicts failures in advance and intelligently manages mobile workforces.
Its hybrid architecture and autonomous decision-making capabilities not only transform operational processes into intelligent workflows but also deliver up to 30% reduction in maintenance costs, driving exceptional cost efficiency.

Industry Challenges
- As of August 2025, managing a rapidly expanding network of 30,000+ EV charging connectors across 81 provinces
- Non-functional or faulty charging stations impacting service quality
- End-user dissatisfaction due to incorrect device status (active/inactive/faulty) shown in mobile applications
- Inefficient planning in fault and maintenance workflows
- Heavy reliance on manual processes (phone calls, emails, spreadsheets) for incident management
- Poor workforce planning and tracking
- Lack of effective field operations management
- Inability to monitor and enforce KPI & SLA compliance

Our Solutions:
- EVCify OpEx AI leverages telemetry data collected from devices and related components to enable:
- Anomaly detection using advanced ML and AI algorithms
- Failure clustering and root cause analysis
- Predictive insights enabling remote issue resolution before on-site intervention
- Smart job order scheduling
- Workforce optimization for field technicians
- Digitalized Health & Safety compliance and monitoring
- Real-time KPI & SLA tracking for transparent service quality measurement
- Advanced analytics and reporting dashboards

Target Market & Use Cases
- EV Charging Network Operators (CPOs)
- Installation & Maintenance Service Providers
- Field Service Teams & Mobile Workforce Companies
- Energy Management & Grid Integration Providers
- Municipalities and Government Agencies
- Domestic & Global e-Mobility Project Managers

Service Modules
- Fault & Maintenance Management
- Workforce Management
- Job Order Management
Mobile Workforce Management
Customer Support Management
- Ticketing System
- Chatbot Integration
Reporting & Analytics
- KPI & SLA Reports
- Job Order Reports
- Fault & Incident Reports
- Customer Support Ticket Reports
- Custom Reports
Third-Party Integrations
- CRM, SAP, IoT Platforms, EV CSMS & more

Objectives
- The platform aims to enhance service quality in the energy sector by ensuring:
- Compliance with Health & Safety standards
- Real-time fault and anomaly detection
- Improved trust in EV infrastructure reliability
- Higher customer satisfaction
- Increased charging point availability & uptime through planned maintenance

Sustainability Impact
- Improved energy efficiency in EV charging infrastructure
- Contribution to carbon emission reduction
- Minimizing downtime from outages and maintenance delays
- Boosting consumer confidence in reliable energy delivery
- Predictive and preventive maintenance reducing overall operational costs and supporting sustainability goals

Revenue Models
- Model 1: On-Premise Deployment
- Annual Licensing Fee
- Annual Maintenance Agreement
- Monthly 24/7 Support Service Revenue

- Model 2: SaaS-Based
- One-Time Setup Fee
- Monthly/Annual Subscription
- Per-User Pricing
- Multiple Package Options

- Model 3: EV CSMS Embedded Module
- Annual Licensing Fee
- Annual Maintenance Agreement
- Monthly 24/7 Support Service

- Additional Revenue Streams (All Models):
- Custom Development Services
- Consulting Services
- Rugged Tablet Device Sales

Current Stage
The project is currently in Prototype / Pre-MVP Development Phase.

Track Record:
Engaged with 50+ leading companies in the EV charging ecosystem in Turkey, including CPOs, hardware manufacturers, and field service providers.
Direct communication with 180+ EV charging operators through other services.
Market validation supported by EPDK regulatory framework and distribution system operators' service quality standards.
Demonstrated 25-30% OpEx cost reduction potential in client workshops and POCs, emphasizing improved customer experience and operational reliability.
Several prospects are considering budget allocation for 2026, and POC agreements under NDA are in progress.

EVCify Roadmap
- EV Charging Technologies
- e-Mobility Solutions
- AI & IoT-Based Operations
- Energy Storage Systems
- Renewable Energy Solutions
- Microgrid Technologies
for all in one software platform.

**Keywords:** Digitalizing Field Service Operations, Artificial Intelligence, Predictive Analytics

**AuthorToEditor:** 2023 EVCharge Show'da 2.cilik ödülü aldığımız EVCify, Electric Vehicle Charging Solutions sunumu içerisinde bir fikir olarak bahsetmiş olduğumuz çözüm, bu yıl "EVCify Teknoloji A.Ş." olarak bir şirkete dönüşmüştür. OpEx AI ise platformumuzun güçlü bir özelliği olarak başta elektrikli araç şarj istasyonları olmak üzere tüm enerji sektörüne yön verecektir. Özellikle ekibimizi finans etme konusunda bir startup firması olarak her türlü mentorluk, stratejik partnerlikler ve finans ödülü firmamıza kısa vadede çok fazla katkıda bulunacaktır. Hakkımızda daha fazla bilgi için: https://evcify.com/

[Abstract:0010] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Hybrid Partnerships Between Charge Point Operators and Energy Giants: A Strategic Proposal for the Electric Vehicle Transition

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Overview
As electric vehicles (EVs) rapidly become more widespread, charging infrastructure is no longer just a technical issue but a strategic cornerstone. Energy replenishment now occurs not only at traditional fuel stations but also through charging devices spread across parking lots, shopping malls, workplaces, and even residences. This shift is creating a new competitive landscape, challenging the centralized distribution models familiar to energy companies.

In this context, hybrid collaboration models between regional charge point operators (CPOs) and traditional energy giants—including technology sharing—present significant opportunities for both operational synergy and strategic flexibility.

Method
This paper explores a proposed hybrid collaboration model to help major energy companies (oil majors) integrate more effectively and flexibly into EV charging infrastructure. The model includes components such as roaming integration, co-branding, operational capability sharing, and diversified energy sources for micro-mobility solutions. The framework is based on field observations from an investor perspective, existing practices, and strategic design analyses.

RESULTS: The analysis shows that such models offer key advantages, particularly in emerging markets: accelerating infrastructure investments, enabling agile adaptation to regulations, and building reliability. However, collaboration processes face vulnerabilities due to organizational culture gaps, differing risk management approaches, and misalignment in decision-making mechanisms.

Implications
The proposed hybrid model can help energy giants move beyond traditional business practices and position themselves more dynamically in the EV market. For CPOs, it may create reputational leverage in sustainability—such as financial and operational benefits, carbon-neutral charging certifications, or renewable energy integration. The presentation provides a strategic framework for understanding the conditions under which such collaborations become viable.

References
The discussion draws on the speaker’s field observations and business model analyses as an investor and strategy developer. Examples like Shell, BP Pulse, and Ionity are supported by sector reports and recent academic publications.

**Keywords:** Charge Point Operators (CPOs), electric vehicle charging infrastructure, emerging markets, energy giants, hybrid partnerships, operational synergy

[Abstract:0012] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# Solar-powered EV charging stations: a sustainable and economically viable solution

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SOLAR-POWERED EV CHARGING STATIONS: A SUSTAINABLE AND ECONOMICALLY VIABLE SOLUTION
Solinved Batarya Teknolojileri San. ve Tic. A.Ş.

Abstract
The global transition to electric mobility is essential for reducing transportation-related greenhouse gas emissions, yet the environmental benefits of electric vehicles depend heavily on the source of electricity used for charging. When powered by fossil fuel-based grids, the carbon reduction potential of EVs is significantly diminished. To address this, Alka Solar focuses on the development of solar powered EV charging stations that integrate high-efficiency photovoltaic (PV) technology with advanced AC and DC charging systems. Leveraging our dual expertise in solar panel manufacturing and intelligent charging solutions, we have designed off-grid and hybrid systems that combine environmental sustainability with economic competitiveness.
Solar energy, as an abundant and renewable resource, offers a zero-emission charging alternative that can be deployed across diverse geographical and infrastructural contexts. Alka Solar, a leading manufacturer specializing in solar panel production and integration, emphasizes the synergy between clean energy generation and high-efficiency charging technology. Our current research includes the design and performance modelling of PV-based charging stations, supported by software simulations and cost-benefit analyses. For example, in an off-grid configuration, a 22 kW AC charger operating at full capacity for six hours per day requires approximately 132 kWh of usable storage. Accounting for inverter and battery efficiencies, the gross capacity rises to around 155 kWh, typically implemented with lithium iron phosphate ($LiFePO_4$) batteries for extended cycle life. Under average solar irradiance of 5 kWh/m²/day and an 80% overall system efficiency, this demand is met with roughly 39 kWp of PV capacity. A three-phase, pure sine wave hybrid inverter rated at 25 kW with at least 1.2× overload capability ensures stable operation, while dynamic load balancing algorithms limit power draw when battery state-of-charge falls below 20%, directing any PV surplus to auxiliary loads or a local microgrid.

The research methodology combines system design and modelling of integrated PV-based charging stations, software simulations to evaluate performance under varying conditions, cost analysis comparing solar-powered versus grid-only stations, and efficiency testing of prototypes. Our findings demonstrate that such systems can effectively eliminate operational carbon emissions, significantly reduce dependency on grid electricity, and achieve substantial cost savings, while enhancing scalability and energy independence. These results position solar-powered EV charging stations as a cornerstone technology for sustainable transport infrastructure.

Field testing of prototypes, following MATLAB/Simulink performance simulations, has validated these sizing assumptions within a ±5% margin. Results demonstrate that fully solar-powered stations can eliminate operational carbon emissions, significantly reduce grid dependence, and achieve competitive levelized cost of energy (LCOE) values—up to 18% lower than grid-only systems over a 10-year horizon. Furthermore, our roadmap includes integrating energy storage, V2G-ready infrastructure, adaptive load management, and modular containerized designs to deliver scalable, intelligent, and future-proof charging solutions. These findings position solar-powered EV charging stations as a cornerstone technology in the sustainable transport infrastructure of the coming decades.

**Keywords:** EV charge, green charging, solar energy, charging with storage,

[Abstract:0015] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Impact of Fast Charging on EV Battery Life and Infrastructure Solutions: A Turkiye-Specific Analysis

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Overview
The rapid growth of ultra-fast DC charging stations (150-350 kW) in electric vehicle (EV) infrastructure is causing significant battery degradation due to high current (3C-4C), creating both sustainability and economic challenges. This study offers technical and strategic solutions for charging operators, with special focus on Turkiye's high-temperature conditions.

Methodology
Our research followed two approaches:
1. Data Analysis: We examined international reports (2022-2024) comparing battery performance between slow (AC) and fast (DC) charging.
2. Standards Review: We analyzed global safety standards (IEC 61851-23 and CE-LVD) for EV charging equipment.

Key Findings
• Fast DC charging (3C) causes 32% more capacity loss over 5 years than slow AC charging (0.3C), increasing annual ownership costs by $1,800 (BloombergNEF 2023).
• Risk of thermal failure is 2.3 times higher with DC charging (CharIN 2023).
• In Turkiye's Mediterranean and Southeastern regions, temperatures above 35°C increase battery degradation by 18-27% during fast charging (Al-Haddad et al. 2023).

Recommendations
1. Technical Solutions:
o Automatically reduce charging speed to 0.5C when battery reaches 80% charge level (SOC).
o Limit maximum charging to 2C in areas with temperatures above 35°C.
2. Certification Requirements:
o Use CE-LVD compliant equipment to protect against voltage fluctuations.
o According to Boston Consulting Group (2024), certified thermal management systems can extend battery life by 22%.
3. Turkiye-Specific Strategies:

o Make temperature sensors mandatory at all charging stations.
o Create special pricing for vehicles with LFP (Lithium Iron Phosphate) batteries, which show 40% less degradation in heat compared to NMC batteries.

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**Keywords:** fast charging degradation, EV battery lifespan, Turkey thermal stress, LFP battery advantages, charging infrastructure standards

[Abstract:0016] [Accepted:Oral Presentation] [Battery systems and technologies used in electric vehicles]

# "Comparative Performance Analysis of LFP and LTO Battery Technologies in Pantograph Charging Scenarios for Electric Buses"

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This study compares the operational performance of two battery chemistries, LFP and LTO, under the increasingly adopted pantograph charging infrastructure for urban electric buses. Initially, CCS2-based charging scenarios are analyzed in terms of daily range and charging time. Then, a pantograph-assisted opportunity charging scenario is simulated to evaluate fast-charging capability, energy efficiency, and operational continuity. Technical parameters such as energy density, charge acceptance rate (C-rate), total capacity, and weight are examined to understand their impact on driving range and charging strategy. Furthermore, the feasibility of sustaining 120 km and 250 km daily operation is tested by integrating multiple intermediate pantograph charging points. The results show that LTO batteries, with their high C-rate capability, are better suited for fast-charging scenarios, while LFP batteries offer longer range and cost advantages. The study emphasizes that battery selection should be guided not only by technical specifications but also by compatibility with real-world operational strategies.

**Keywords:** Battery Performance, Electric Buses, LFP Battery, LTO Battery, Pantograph Charging

[Abstract:0018] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# The core pillars for an excellent EV charging experience

Petar Georgiev
Petar Georgiev

The electric vehicle charging industry is at a pivotal inflection point. As EV adoption moves from early adopters to the mass market, the focus is shifting from simply deploying hardware to providing a world-class, seamless customer experience.

The market now enters a critical window of opportunity that will fundamentally separate industry leaders from those who fail to adapt. Legacy operational models, often siloed and hardware-centric, are no longer sufficient to meet soaring customer expectations for reliability, transparency, and convenience. This abstract explores the strategic transition required to dominate the next decade of e-mobility by prioritizing a customer-first approach.

The conclusions are based on a case study methodology building on our experience at AMPECO as a global software provider powering networks in over 70 countries. Our approach involves a dual-pronged analysis of market dynamics and operational performance. We analyze a comprehensive dataset of millions of charging sessions to identify key customer pain points—such as failed sessions, opaque pricing, and lack of interoperability. Simultaneously, we examine the operational models of successful companies that are leveraging a software-first approach to address these issues. We use these insights to model and test new operational frameworks that can scale efficiently and deliver superior customer satisfaction. For fast growing EV charging networks, the primary challenge is ensuring consistent network utilization and maximizing uptime across a rapidly expanding, fragmented portfolio of chargers. Real-time monitoring and centralized management are crucial for ensuring a reliable service.

Network reliability and issue resolution

Managing a large-scale EV charging network requires a systematic approach to maintenance and issue resolution - a fragmented and reactive management style that can lead to operational inefficiencies, lost revenue, and reduced service reliability.

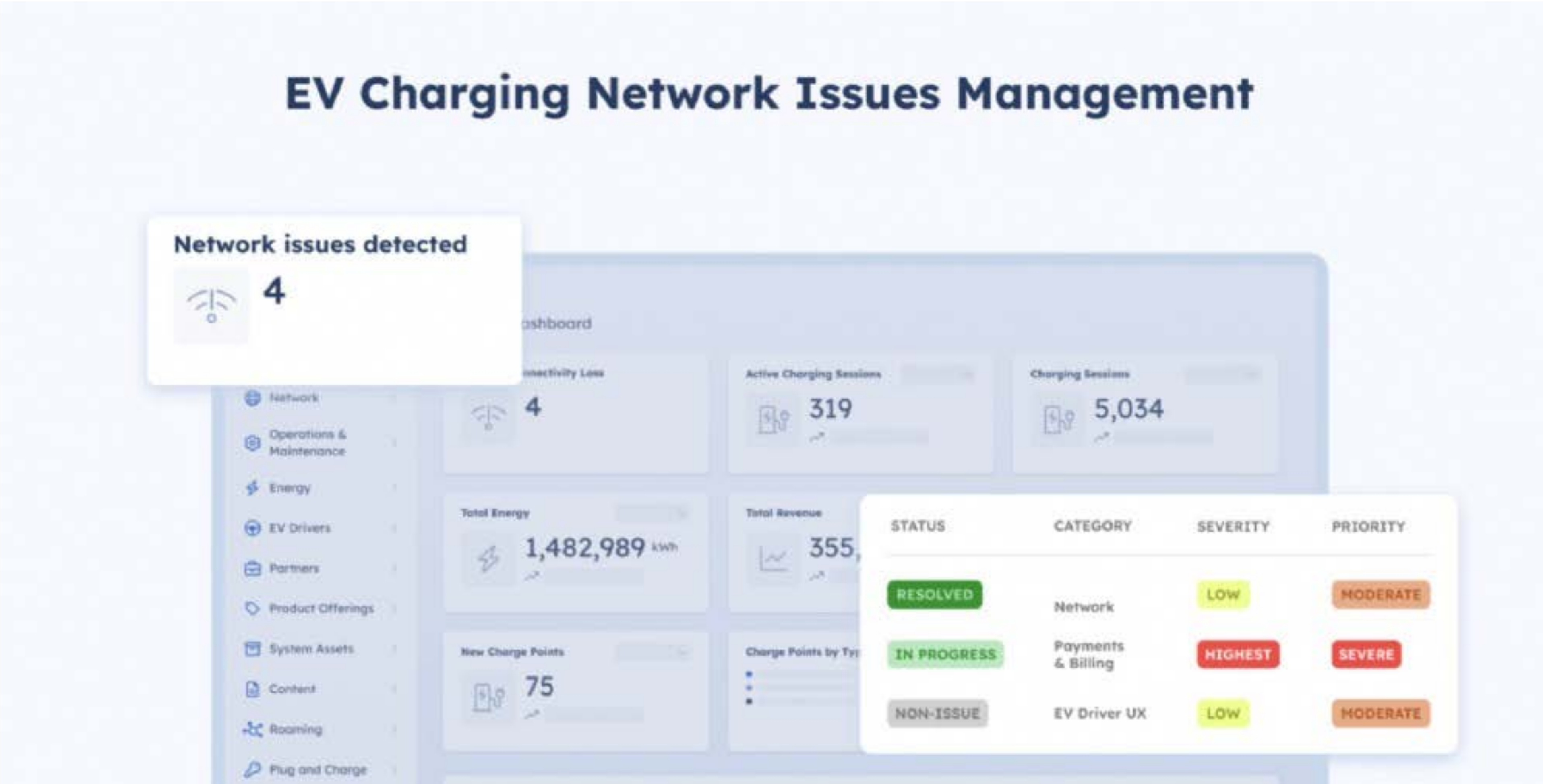
We'll share more insights about AMPECO's Issues Detection functionality that provides a centralized and structured system for this purpose. The tool enables operators to automate the creation, assignment, and tracking of issues across a diverse range of categories, including network infrastructure and payment systems.

We'll speak about issue detection at every single point of interaction - from a driver's initial search for a charger to the moment they receive their final invoice. All these are crucial touchpoint that shape their perception of a brand, directly impacting customer loyalty and a network's long-term commercial success.

The comprehensive data capture and filtering capabilities throughout this process provide a valuable knowledge base for trend analysis, enabling operators to move from day-to-day firefighting to strategic decision-making about infrastructure investments and operational improvements.

**Keywords:** EV, charging, infrastructure, driver, reliability, CPO

**dashboard visual**




**AuthorToEditor:** Thank you for your attention

[Abstract:0022] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# The Future of Turkey's Electric Vehicle Charging Infrastructure: Risks and Opportunities

Rıfkı Çolak
Siemens Turkiye

Electric vehicles are transforming not only transportation habits but also urban energy consumption, the organization of living spaces, and the approach to sustainability. While Turkey sits at the center of this transformation, the future of its electric vehicle charging infrastructure presents both strategic opportunities and risks that must be managed.

One of the most critical risks today is the potential for high demand on the energy grid due to the rapid increase in the number of electric vehicles. In scenarios where tens of thousands of vehicles are charged simultaneously in the coming years, if smart management systems are not implemented, the impact will extend beyond charging stations to the broader urban energy infrastructure, potentially causing capacity issues and service interruptions. Another significant risk is the lack of standardization. Incompatibilities in infrastructure and software protocols negatively affect the user experience and slow the integration process within the sector. This creates uncertainty for investors and can hinder technological innovation and efficient integration into international markets.

The reliability of the service infrastructure is also a critical factor. Charging stations must be dependable not only during installation but also throughout daily operations; proactively preventing faults, quickly resolving interruptions, and providing users with timely support play a decisive role in the widespread adoption of e-mobility.
Ensuring a sustainable and reliable infrastructure requires a comprehensive service and digital solution approach. In this context, throughout installation, integration, and maintenance processes, continuous local support combined with remote services should be provided, and high device uptime and operational continuity must be secured. Through digital services and a customer portal, charge point management, 24/7 support, transparent ticket tracking, and personalized notifications should be ensured; on-site first response and spare part provision further strengthen the reliability of the infrastructure and user satisfaction.

Turkey’s greatest opportunity lies in designing e-mobility infrastructure not merely as a system to meet today’s transportation needs but as an ecosystem continuously enhanced by digital services, supported by reliable operations, and driven by technology-focused solutions. With this approach, electric vehicle charging infrastructure can become a cornerstone of sustainable transportation as well as strategic national development.

**Keywords:** Digital Services, Operational Continuity, Risks, Service Infrastructure, Charging Infrastructure, Opportunities

[Abstract:0023] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Growing the EV Chargers in the Turkiye Market and the Specs of the Chargers

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According to the Energy Market Regulatory Authority's (EMRA) Monthly Charging Service Market Statistics for July 2025, the number of EVs increased from 198,002 in January 2025 to 291,775 in July 2025. This increase in the number of EVs more than doubles the impact on the number of charging operations. In January 2025, the total number of charging operations was 1,034,827, while in July 2025, it was 2,242,379.

While the number of charging stations and electricity consumption per charge are increasing, the charging time per charge is decreasing. The ranges of vehicles entering the market and the number of newly installed high-speed charging stations are increasing daily.

I would like to provide in-depth information about market details in my speech.

**Keywords:** EMRA, EV Chargers, Turkiye, Fast Chargers, Charging Behaviors, Turkish Charging Market

[Abstract:0025] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# İnovasyon Yolculuğu: Türkiye’nin Küresel Otomotiv Sahnesindeki Rolü Şarja Devam: Elektrikli Araç Altyapısı ve Teknolojilerinin Gelişimi

Firat Ergün
OTTO CAR SERVİS;SAKARYA;TURKİYE

İnovasyon Yolculuğu: Türkiye’nin Küresel Otomotiv Sahnesindeki Rolü
Konuşmacı Notları:
“Türkiye otomotiv sektöründe hızla küresel bir oyuncu konumuna geliyor. TOGG ve diğer yerli üretim projeleriyle sadece araç üretmiyoruz; batarya teknolojileri, yazılım ve bağlantılı araç çözümleri ile inovasyon kapasitemizi artırıyoruz. Artık Türkiye, sadece üretici değil, aynı zamanda teknoloji geliştiren ve çözüm üreten bir ülke olarak küresel sahnede yer alıyor.”
Slayt 2 – Şarja Devam: Elektrikli Araç Altyapısı ve Teknolojilerinin Gelişimi
Konuşmacı Notları:
“Elektrikli araçların yaygınlaşması için güçlü bir şarj altyapısı şart. Şehir içi ve otoyollarda hızlı şarj istasyonları artıyor. Ayrıca çift yönlü şarj ve kablosuz şarj gibi ileri teknolojilerle altyapıyı daha esnek ve sürdürülebilir hale getirebiliyoruz. Yenilenebilir enerji entegrasyonu sayesinde maliyetleri düşürüp çevresel etkileri azaltmak mümkün.”
Slayt 3 – Rekabet Dinamikleri: Küresel E-Mobilite Pazarında Konumlanma
Konuşmacı Notları:
“Global e-mobilite pazarında Avrupa, Çin ve ABD önde. Türkiye’nin hem üretim kapasitesi hem de coğrafi avantajı, rekabette güçlü bir pozisyon sağlıyor. Rekabet avantajı, inovasyon, altyapı yatırımları ve batarya teknolojilerine odaklanan firmalar tarafından kazanılıyor. Biz de Oto Kar Servis olarak bu dönüşümün içinde yer alıyoruz.”
Slayt 4 – Hızlı Şarj İstasyonlarında Enerji Depolama Çözümleri: Zorluklar ve Fırsatlar
Konuşmacı Notları:
“Hızlı şarj istasyonları yüksek güç ve şebeke stabilitesi gerektiriyor. Bu nedenle enerji depolama çözümleri büyük önem taşıyor. Batarya depolama sistemleri, şarj sırasında pik yükleri dengeliyor. Burada büyük fırsatlar var: yenilenebilir enerjiye dayalı hızlı şarj altyapısı, bakım ve servis hizmetleri sunmak. Ancak yüksek maliyet ve teknoloji adaptasyonu da birer zorluk.”
Slayt 5 – Ağır Hizmet Araçlarının Elektrifikasyonu: Zorluklar ve Fırsatlar
Konuşmacı Notları:
“Ağır hizmet araçlarının elektrik dönüşümü hem zorlu hem de fırsat dolu bir alan. Büyük bataryalar, şarj altyapısı ve yüksek voltaj güvenliği zorluklar

arasında. Ama işletme maliyetlerinde düşüş, çevresel fayda ve filo yönetimi açısından büyük fırsatlar sunuyor. Otto Car Servis olarak bu alanda da çözümler geliştiriyoruz."
Slayt 6 – Otto Car Servis: Biz Neler Yapıyoruz?
Konuşmacı Notları:
"20 yılı aşkın tecrübemiz ve 13 yıllık bağımsız servis deneyimimiz ile elektrikli araç tamirinde uzmanız. Batarya tamiri, DC/DC inverter ve elektronik modül onarımları gerçekleştiriyoruz. Ayrıca şarj altyapısı ve güneş enerjili sistemlerle entegrasyon çalışmalarımız devam ediyor. Ağır hizmet araçları için elektrik dönüşüm projeleri de yürütüyoruz."
Slayt 7 – Otto Car Servis: 2030'a Hazır mıyız?
Konuşmacı Notları:
"2030'a hazırız çünkü yüksek voltaj ve batarya teknolojilerinde uzman bir kadroya sahibiz. Yeni nesil arıza tespit cihazları ve altyapı yatırımlarımızla Türkiye'de elektrikli araç tamirinde öncü olmayı hedefliyoruz. Misyonumuz: Elektrikli gelecekte müşterilerimize güvenilir, hızlı ve teknolojik çözümler sunmak."

**Keywords:** EV,CHARGE,CAR,SOLAR ENERGY

[Abstract:0026] [Accepted:Oral Presentation] [New business models related to electric vehicles]

# Regulatory Constraints and Resource Allocation: The Sub-Optimal Opportunity for Innovation in E-Mobility Startups

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Istanbul Technical University

The e-mobility sector is a complex ecosystem where innovation is profoundly shaped by regulatory and market uncertainties. This paper argues that these external constraints—from fragmented city-level permits to data privacy laws like GDPR and market unpredictability—create a strategic dilemma for startups. These firms must choose between investing in costly, in-house optimization models to achieve operational excellence or allocating resources to more direct market penetration strategies like lobbying and pricing. Our core thesis is that in an environment where regulations force a sub-optimal outcome regardless of a startup's operational excellence, the rational choice is to reallocate resources away from internal optimization and toward external, market-shaping activities.

This study employs a conceptual and analytical framework grounded in a comprehensive literature review and a strategic analysis of current industry dynamics. We draw upon key economic theories, including the Law of Diminishing Returns and the Resource-Based View, to explain the core trade-offs faced by startups. The analysis is supported by qualitative evidence from industry reports and a comparative analysis of global e-mobility ecosystems. Finally, the paper introduces a conceptual "shared optimization unit" as a solution and assesses its viability through a comparative evaluation of governance models, including a private, state-supervised, and hybrid consortium structure.

Our analysis reveals that the high cost and diminishing returns of internal optimization teams make them financially unviable for most startups. The "pilot purgatory" created by fragmented regulations and the "right to erasure" under GDPR act as significant barriers to data-driven innovation, reducing the value proposition of costly R&D. We demonstrate that this environment leads startups to prioritize direct market penetration, which, while rational for individual firms, results in a sector-wide loss of efficiency. A centralized, shared optimization unit is proposed as a solution to this collective action problem. By leveraging economies of scale and technologies like federated learning, such a unit could provide sophisticated, AI-powered optimization services for a fraction of the cost of an in-house team, democratizing access to critical tools and fostering a more level playing field for all market participants.

This paper posits that a centralized, shared optimization unit is not merely a technical solution but a strategic asset that could address systemic inefficiencies in the e-mobility ecosystem. We argue that the optimal governance model for this unit is a hybrid consortium—owned and operated by its members—as it balances the agility of a private company with the trust and shared ownership of a public entity. By adopting a "coopetition" framework, where firms collaborate on pre-competitive activities like optimization while competing on their core products, the sector can unlock greater collective value. We conclude with a call for policymakers and industry leaders to initiate a dialogue on creating such a unit, as it is a critical step for accelerating the e-mobility sector's transition from an "Era of Ferment" to a scaled, efficient, and profitable industry.

**Keywords:** Startups, Policy, Optimization
**AuthorToEditor:** Full paper will be preared in due time.

[Abstract:0031] [Accepted:Oral Presentation] [New business models related to electric vehicles]

# Enabling Urban Electrification: Business Models and Grid Integration for On-Street EV Charging — Insights from London


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The rapid adoption of electric vehicles across Europe is reshaping urban mobility and creating new challenges for charging infrastructure development. For many EV owners today, home charging is not simply a preferred option but often the only viable solution, as existing on-street charging infrastructure remains largely unsuitable for regular daily use. In dense urban areas, this challenge is particularly acute — for example, in London, approximately 56% of households lack access to private parking, making public charging a necessity rather than a choice. As a result, on-street EV charging is emerging as a critical enabler of large-scale electrification, yet its economic viability and integration into local energy systems remain insufficiently explored.

This research investigates business models for on-street EV charging by comparing three representative use cases: home-based charging, on-street charging, and reliance on high-power fast-charging hubs. The analysis is based on a comprehensive dataset collected in London during 2024–2025, comprising more than 1.9 million data points from over 12,9 thousand public charging stations. User behaviour, infrastructure utilisation rates, cost structures, and energy demand profiles were derived from this dataset. For energy estimations, power levels of individual charging stations were used as the primary reference rather than exact energy consumption per session.

Based on this dataset, representative charging station usage profiles were developed to capture distinct patterns of infrastructure utilisation. Since the dataset is fully anonymised, these profiles describe station-level activity rather than individual EV behaviour and were used as the basis for modelling grid impact and evaluating the potential role of Vehicle-to-Grid (V2G) services in enhancing energy flexibility.

To complement this station-level analysis, EV charging behaviour was incorporated to provide a broader user-centric context. Research indicates that approximately 70% of EV charging in Europe currently takes place at home or work, while surveys show that around 50% of charging sessions occur at residences, 23% at public sites, and 10% at workplaces. Fast chargers, by contrast, are typically used during longer trips or when no home or destination charging is available. This creates a significant challenge for urban residents without private driveways, who rely almost exclusively on public charging networks. Existing on-street networks, as a rule, operate with pricing structures designed for occasional use, making regular charging economically unattractive. This misalignment between infrastructure design, user needs, and pricing models underpins the focus of this study on developing sustainable business models for on-street charging.

The findings highlight significant differences in operational economics and grid implications. On-street charging is essential for equitable EV adoption but entails higher infrastructure and operational costs compared to home charging. Fast-charging hubs offer stronger short-term revenue potential but increase peak-load stress on local grids and partially offset the economic benefits of switching from fossil fuels to electricity. In contrast, integrating dynamic charging schedules and enabling V2G functionality within on-street chargers unlocks opportunities to optimise grid utilisation, defer costly infrastructure upgrades, and create new revenue streams for operators. Unlocking these opportunities demands a coordinated shift in on-street charging strategies, integrating technical innovation, policy support, and viable business models. Yet, our analysis reveals that such benefits may not be deliverable across all market segments.

Future work will extend the analysis with pilot deployments to validate economic feasibility and quantify the benefits of integrating on-street charging into distributed energy systems.

**Keywords:** On-street EV charging, Business models, Smart charging, Vehicle-to-Grid (V2G) Urban mobility, EV Charging infrastructure

[Abstract:0032] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Engineering Challenges in EV Charger Compliance: India Perspectives

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The rapid adoption of electric vehicles (EVs) worldwide underscores the need for scalable, reliable and efficient charging infrastructure. In this context, off-board AC/DC chargers play a pivotal role and are subject to rigorous type testing to demonstrate compliance with regulatory safety and performance requirements. These evaluations typically address electrical safety, electromagnetic compatibility (EMC), interoperability, environmental endurance, and mechanical robustness.

This paper examines the mandatory compliance framework in India as a case study and highlights common failure modes observed during validation of off-board AC and DC chargers. Specific emphasis is placed on challenges related to electrical safety, EMC performance, and interoperability factors that are equally critical in other global markets. The outcomes are intended to support charger manufacturers and developers in proactively identifying compliance risks, refining design practices, and strengthening product reliability. Beyond the Indian context, the insights are relevant to global stakeholders as they demonstrate how region-specific compliance testing can uncover systemic engineering challenges that are universally applicable. Ultimately, bridging these engineering gaps is essential for accelerating the deployment of safe, efficient, and interoperable EV charging infrastructure

The Bureau of Indian Standards (BIS) has formulated and released a comprehensive set of Indian standards for Electric Vehicle (EV) charging stations, specifically catering to the needs of both electric two-wheelers (e2Ws) and electric four-wheelers (e4Ws). These standards ensure uniformity in design, safety, and performance across various types of charging infrastructure deployed across the country.

These standards fall under the IS 17017 series, which comprehensively outlines the compliance requirements for AC and DC charging systems, including general specifications, EMC requirements, connector types, communication protocols and safety guidelines for operation. By establishing this structured regulatory framework, BIS enables charger manufacturers, infrastructure developers, and utilities to implement EV charging solutions that are safe, interoperable, and scalable, thereby contributing to the development of a reliable and future-ready charging ecosystem aligned with India’s electric mobility goals

Subsequent sections outline the typical issues identified in electrical testing, interoperability validation, and EMC performance evaluations.

1. Electrical tests and observed failures: Electrical compliance testing based on IS17017 standards is essential for validating the safety, performance, and compatibility of electric vehicle charging equipment (EVSE). These tests cover critical assessments such as verifying insulation resistance, ensuring

protective earth continuity, detecting residual currents, and confirming proper functioning of over-voltage and over-current protective devices, along with the integrity of communication protocols between the charger and the vehicle. In this section we will explore the typical failures occurring during electrical testing

2. Interoperability tests and observed failures: Interoperability ensures that off-board EV chargers adhere to applicable standards to operate safely and effectively with a wide range of electric vehicle models. This requires compliance with standardized control pilot signaling, compatibility with communication protocols, and conformance to mechanical and electrical interface connector specifications. Together, these elements enable seamless and reliable charging interactions across diverse EVs and charging systems.
The primary objectives of CCS2 interoperability testing are:
1. Protocol Compliance: Ensure EVSE adheres to ISO 15118 and DIN 70121 protocols using PLC.
2. Communication Robustness: Validate handshake, message exchange, and timing performance.
3. Charging Process Validation: Verify complete session from plug-in to power delivery to shutdown.
This section analyzes the interoperability issues observed during compliance testing, along with their technical causes and potential mitigations. Observations indicate that failures often arise from timing mismatches in PLC message sequences, deviations from required voltage/current ramp profiles, impedance mismatches during cable checks, and state machine synchronization errors.

3. Critical EMC tests and observed failures: As the deployment of electric vehicle (EV) infrastructure accelerates, electromagnetic emissions from high-power charging systems can disrupt nearby communication, control, and safety systems. IS 17017-21-2 defines limits and methods of measurement for EMC phenomena for Immunity and Emission tests for conductive off-board chargers are discussed in this section

**Keywords:** EVSE- Electric vehicle supply equipment, IS- Indian Standards, CCS2- Combined Charging System

[Abstract:0033] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Competition Law in the Electric Vehicle Charging Market: A Look at the Future in Light of Competition Authority Jurisprudence

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The Application of Competition Law to Electric Vehicle Charging Services Markets: A Turkish Perspective
Overview: Significance and Background
The global transition to electric vehicles (EVs) is reshaping the transportation and energy sectors, with EV charging services emerging as the critical infrastructure underpinning this revolution. This market, however, is characterized by high fixed costs, network effects, and significant regulatory intervention, creating a fertile ground for potential anti-competitive practices. The significance of this topic lies in ensuring that this nascent market develops competitively, avoiding monopolistic structures that could hinder innovation, inflate prices for consumers, and ultimately delay the achievement of sustainability and energy independence goals. From a Turkish perspective, analyzing this through the lens of the national competition authority's (Rekabet Kurumu) existing jurisprudence provides a robust predictive framework.

METHODOLOGY: Analytical Approach
This analysis employs a legal and case study-based methodology rooted in comparative law reasoning. The primary approach involves:

Identifying Analogous Markets: Established markets with similar characteristics (e.g., petrol stations, telecommunications, digital platforms) are identified to draw parallels.

Reviewing Precedent: Key decisions by the Turkish Competition Board concerning these analogous markets are analyzed to extract core legal principles and the Board's enforcement trends.

Application by Analogy: These established principles are applied to the specific dynamics of the EV charging services market to forecast potential regulatory challenges and outcomes.

Synthesis: The findings are synthesized to provide guidance for market participants and policymakers, highlighting areas of high regulatory risk and opportunity.

RESULTS: Primary and Supporting Findings
The analysis yields clear predictions on how the Turkish Competition Board is likely to approach the EV charging market:

Market Definition: The Board will likely define geographic markets very narrowly (e.g., a specific highway corridor or urban district), mirroring its

approach in the petrol station market (e.g., BP/CEPSA decision). Product markets may be separated into charging infrastructure operation and retail charging services.

Vertical Agreements (Exclusivity): This is the area of highest regulatory risk. Solus/exclusivity agreements between a location owner (e.g., a mall, parking lot) and a single charging operator will almost certainly be scrutinized and likely deemed restrictive, based directly on the precedent set in the OPET/TOTAL case concerning petrol stations.

Abuse of Dominance: The "essential facility" doctrine, as applied in telecommunications cases (TTNET/Nettele, Türk Telekom), could be extended to unique, high-capacity charging locations on critical routes, obliging operators to grant access to competitors.

Data and Discrimination: The Board's reasoning in digital platform cases (Google, Meta) regarding self-preferencing and data control will likely apply. A dominant charging network operator favoring its own stations on its app or restricting data access could be found to have engaged in discriminatory practices.

CONCLUSIONS: Key Takeaways and Next Steps
The key conclusion is that the Turkish Competition Board will not treat the EV charging market in a regulatory vacuum but will apply its well-established principles from analogous sectors vigorously.

Implications: Operators must proactively design their business models for compliance. This means avoiding long-term exclusivity clauses, planning for interoperability, and ensuring non-discriminatory data and access policies. Investors must factor in these regulatory risks.

Proposed Next Steps:

For Operators: Conduct a compliance audit based on the OPET/TOTAL and digital platform precedents.

For Policymakers: Develop clear guidelines that encourage investment while mandating interoperability and transparent, non-discriminatory access to charging networks.

For the Competition Authority: Issue a preliminary "guidance letter" or sector inquiry report to provide much-needed legal certainty and steer the market towards a competitive structure from its inception, preventing costly competition problems in the future.

References (Illustrative List of Turkish Competition Board Decisions)

**Keywords:** Competition law, EV charge markets, horizontal and vertical agreements, exclusive agreements, abuse of dominant positions, administrative fines

[Abstract:0037] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Safety of EV Charge Stations- TS 13912

Anil Erdinç Tüfekçi
TORA ŞARJ

Safety is becoming increasingly important in the electric vehicle charging ecosystem. This is due to the rapid increase in the number of AC and DC charging units and stations, of various brands and models, in both indoor and outdoor areas. The development of the TS 13912 standard is considered one of the key legal regulations in this regard. With the updated standard, the first inspections of field systems are planned to be conducted independently at the beginning of 2025.
Our presentation will examine developments in the scope of the TS 13912 standard regarding electrical, fire, and other OHS risks. Accidents experienced in the sector in our country and globally, legal developments, and the provisions of the TS 13912 standard will be evaluated.
The challenges of the standard, some unclear issues, practitioners, and inspection methods will be discussed. Issues not addressed within the standard, other inspection needs, and risks will be discussed.
Resources:
• TS 13912 Safety Rules for Electric Vehicle Charging Stations, January 2025
• EV Charging Station Permitting Guidebook, January 2023

**Keywords:** Safety, EV, TS 13912, Charge Station

[Abstract:0039] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Reducing charging speed anxiety and contributing toward efficient EV charging

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Overview
Switching from ICE vehicles to EVs is a necessary and fundamental step on the roadmap towards net zero. The industry is focused on improving charging efficiency and reducing charge session time cited most valuable by users. Higher currents dictate the need for higher rated components generating more heat and needing more space which is contradictory with manufacturer driven trend of more compact single PCB based AC chargers. Of issue is dual charging output type (22kW) with performance most at risk. Typically, Charger mounted outside can easily result in internal air temperature cycling >70 °C leading to degradation in performance and durability despite output throttling. Utilizing a low Contact Resistance (CR) switching device (4-pole relay) can contribute to shorter, more efficient charge cycles with an average lower temperature rise aiding electrical life.

OMRON aims to contribute toward Carbon Neutrality. Through market study, and especially feedback of key stakeholders in hot countries such as Turkey we determined energy savings through more efficient charge cycles to be an attractive and vital value-added proposition in the expanding AC Charger market segment.

"[“*Between 250,000 and 600,00 22kW charging points installed base is projected to exist in Turkey by 2030 [see Table 3].
Coincidentally Omron noted that an estimate of the distribution grid impact (measured by the additional capacity and investments in distribution grid lines and transformers, voltage violations and overloading projected to 2030 developed in Turkey based on real grid data that represented Aegean, Central Anatolia, Marmara and Mediterranean together with Turkey's Energy Market Regulatory Authority (EBDK) enacting an acceleration in the adoption of electric car charging stations and new regulation allowing EV drivers to access public charging stations and pricing based on a kilowatt-hour basis"]" was keenly felt denoting the need for efficient, shorter charging times. This motivated us to consider developing a 4-pole relay that could effectively contribute lower heat generation compared to existing devices

Methodology - Lower heat generation by definition
The development of an entirely new relay product with lower heat generation was necessary and to characterize the heat generation issue to be solved and quantify the magnitude of the improvement that can be gained. Omron applied its core competencies with focus to heat transfer using simulation, CAE and real-world tests to determine that the reduction in Contact Resistance offered the best way to achieve lower heat dissipation.
Excessive heat for extended time can exact unwelcome serviceability issues leading to potential loss of revenue for Site Providers and Charge Point Operators (CPOs). At worst in can lead to catastrophic failure. Any reduction of heat level and fast deltas in charge cycles can positively contribute towards reducing the drying effect of the PCB inside the charger.

RESULTS: CR is characterized by initial value under full load conditions and ideally should be as low as possible and must meet relevant Regulatory standards combined with “mechanically coupling”. Omron conducted a simulation to illustrate the value of low initial CR. Consider that an increase of just 1mΩ can elevate load terminal temperature rise by up to approx.18 °C. Utilizing a relay with initial low CR relay (≤1mΩ compared to typical industry 2-3 mΩ) can ensure potential result in double-digit load terminal temperature reduction in heat dissipation and can be an asset in maintaining good electrical health of the AC wallbox or pedestal charger.

Omron’s new 4-pole relay G9KC utilizes an optimized structure that helps achieve lowest initial CR [see Fig. 13 and 16].
As an additional determination for checking low CR and low heat generation of G9KC we conducted a series of real-world typical usage charging A-B comparison tests with existing relays. In all cases typical charge session could be fully characterized confirming the good low heat generation performance of G9KC. Notably inrush current and any contact burning was non-existent promoting VCR stability.

CONCLUSIONS:
Collective efforts derived from the market feedback, resistive theory, simulation, and empirical work confirmed that low CR is of significant value, meeting the high demands of all Stakeholders in the supply chain and improving both end user experience with faster and more efficient charge cycles. Our technical and manufacturing competence realized an **Award Winning Relay G9KC that today provides lowest CR currently available in the market in alignment with our sustainability principles.

With a policy of continuous improvement, we continue to work to further reduce CR in G9KC typically below 1mΩ and now also embody this theme in all our new relay products. Low CR relays will help towards keeping heat generation under control.

References
* SHURA Energy Transition Center
** Elektra Awards 2024

**Keywords:** low,heat,generation,CR,optimized

**Contact resistance difference**

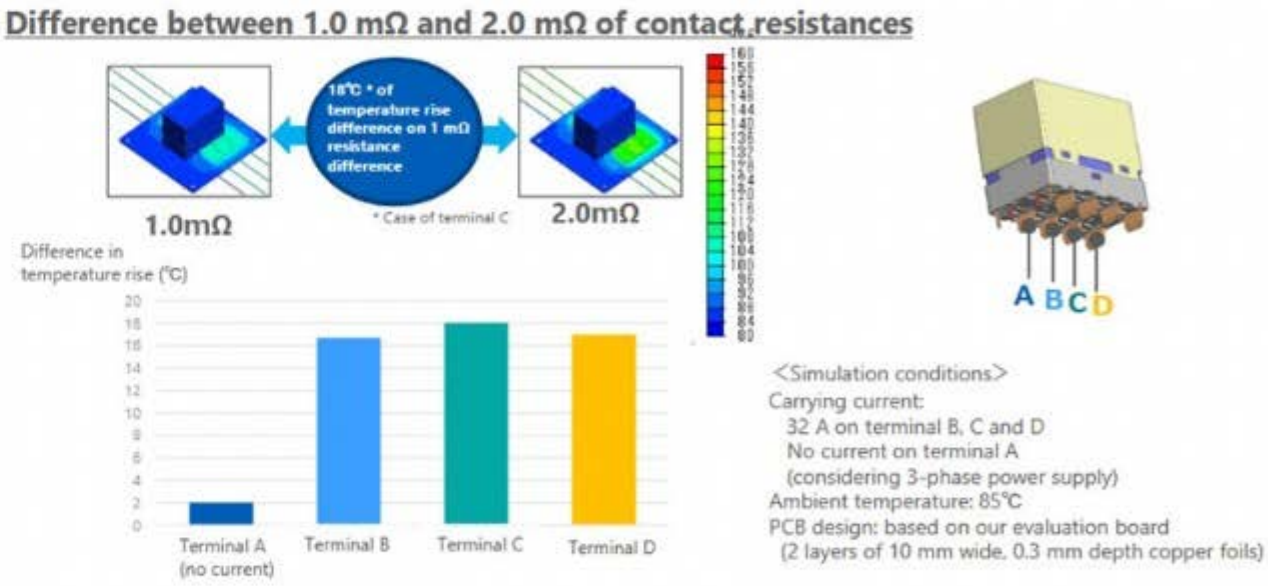


Fig. 16 Thermal simulation result considering difference in contact resistance

**distribution of initial CR G9KC**

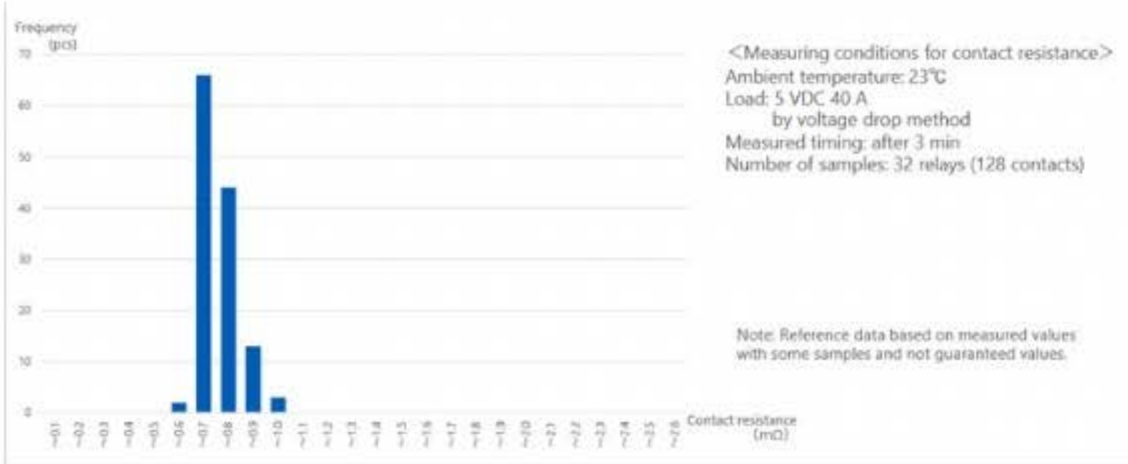


Fig 13. Distribution of initial contact resistance G9KC

**Omron G9KC 4-pole relay**

**Table 3**

***Table 3:*** *Estimations of the total number of electric vehicle charging points in the country in 2030*

| Scenario | Rating (kW) | Moderate-growth | | High-growth | |
|---|---|---|---|---|---|
| Charging case | | Home charging | Public charging | Home charging | Public charging |
| AC1 – home (AC1 H) | 2.3 | 78,160 | 78,160 | 193,953 | 193,953 |
| AC2 – home (AC2 H) | 3.7 | 182,372 | 182,372 | 452,557 | 452,557 |
| AC2 – work (AC2 W) | 22 | 52,106 | 52,106 | 129,302 | 129,302 |
| AC2 – public (AC2 P) | 22 | 46,896 | 93,791 | 116,372 | 232,744 |
| DC3 – public (DC3 P) | 100 | 5,211 | 10,421 | 12,930 | 25,860 |
| **Total** | | **364,745** | **416,580** | **905,114** | **1,034,416** |

**AuthorToEditor:** Please find attached materials for your consideration. Please don't hesitate to contact me directly should you have any questions.

[Abstract:0040] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Enhancing Bluetooth-Based Security Against Replay Attacks in Electric Vehicle Chargers

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Overview
With the increasing prevalence of electric vehicle (EV) chargers, the need for user-friendly and secure communication has become critically important. Bluetooth-based mobile application control provides users with the flexibility to manage the charging process remotely. However, this feature is vulnerable to cybersecurity threats such as replay attacks, making it necessary to protect the system against unauthorized access.
Method
In this study, two security mechanisms were developed to prevent the reuse of encrypted packets transmitted over Bluetooth:
1. Timestamp Verification – A sending time was added to each packet, and packets outside the acceptable time window were rejected.
2. Sequence Number Control – Incremental sequence numbers were added to packets, and packets with unexpected or duplicate numbers were invalidated.
By applying both methods together, the goal was to prevent both rapid and delayed replay attacks.
RESULTS: • Before the security mechanisms were activated, copied packets were accepted by the device.
• After applying the methods, the same packets were observed to be rejected.
• The system became resistant to replay attacks, and its security level was improved in compliance with international standards.
CONCLUSIONS: This study presents an effective and low-cost solution to enhance the security of Bluetooth-based control in EV chargers.
• Lessons Learned: Encryption with static keys alone is not sufficient. Packets must be made single-use.
• Recommended Next Steps: Plans include further strengthening security through cryptographic nonce generation, mutual authentication, and cloud-based security services.

References

1. ISO/IEC 15118: Road vehicles – Vehicle to grid communication interface.
2. IEC 61851: Electric vehicle conductive charging system.
3. ISO/SAE 21434: Road vehicles – Cybersecurity engineering.
4. NIST SP 800-53: Security and Privacy Controls for Information Systems.

**Keywords:** Electric Vehicle Chargers, Bluetooth Communication, Replay Attack, Cybersecurity, Timestamp Verification, Sequence Number Control

[Abstract:0042] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# Merkez Cihaz Üzerinden Dinamik Yük Dengeleme ile Çoklu Şarj Noktası Yönetimi ve Yeni İş Modelleri

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Amaç
Elektrikli araç kullanımının hızla artması, aynı alanda bulunan çoklu şarj istasyonlarının daha verimli yönetilmesini gerekli kılmaktadır. Bu bildiride Volti Ar-Ge tarafından geliştirilen Merkezi Denetim Modülü (CCM) çözümü tanıtılmaktadır. Çözüm, tek bir merkez cihaz üzerinden çoklu istasyonun hem merkezi yazılım sistemine (CSMS/CPMS) bağlanmasını hem de dinamik yük dengeleme (DYD) bilgisinin sahadaki alt istasyonlara dağıtılmasını sağlar. Bu yaklaşım yalnızca altyapı verimliliğini artırmakla kalmaz, aynı zamanda katmanlı üyelik, abonelik ve önceliklendirme temelli yeni iş modellerine de kapı açar.

Yöntem ve Kapsam
CCM, Banana Pi M2+ üzerinde Linux tabanlı bir yazılımla çalışmaktadır. CSMS bağlantısı kablolu ağ üzerinden, saha içi iletişim ise LoRa ya da kablosuz erişim noktası aracılığıyla kurulmaktadır. Yazılım mimarisi OCPP 1.6J iletişim kuralına dayalıdır ve açılış bildirimi, kalp atışı, yetkilendirme, durum bildirimi, sayaç değerleri ve uzaktan başlatma/durdurma gibi temel işlemleri desteklemektedir. DYD verisi, değişiklik algılamalı yayın modeliyle tüm istasyonlara aktarılmaktadır. Sistem, sahada kolay kurulum için otomatik istemci/erişim noktası geçişleri, paket kurulumu, hizmet yöneticisi desteği ve günlük dosyalarının dönüşümlü saklanması gibi özelliklerle hazırlanmıştır.

Bulgular
Çözüm, hem açık kaynaklı hem de ticari merkezi yazılım sistemleriyle denenmiş, kararlı bağlantı ve otomatik yeniden bağlanma işlevleri doğrulanmıştır. Çoklu şarj noktasının tek bir kimlik üzerinden yönetilmesi başarıyla gösterilmiş, DYD'nin değişiklik temelli yayın yapısı sayesinde gereksiz iletişim yükü azalmış ve tepkiler hızlanmıştır. Yapılan simülasyonlarda, istasyonların güç taleplerine anında yanıt verebildiği ve altyapının daha dengeli kullanıldığı görülmüştür. Ayrıca, iş modeli senaryolarında Premium üyelerin yoğun saatlerde daha kısa bekleme yaşadığı, düşük güç seçeneği kullananların ise indirimli şarjdan yararlanabildiği gözlemlenmiştir.

Çıkarımlar
CCM tabanlı DYD yalnızca teknik bir çözüm değil, aynı zamanda işletmeciye yeni gelir kaynakları sunan bir modeldir. Örneğin:

- Öncelikli üyelik ile kullanıcıya her zaman belirli bir güç tahsisi,
- Kademeli paketler (ör. bronz, gümüş, altın) ile farklı güç seviyeleri ve fiyatlandırma,
- Anlık güç artırımı ile kısa süreli yüksek hız karşılığında ek ücret,
- Yoğunluk veya saat bazlı indirimler,
- Filo planları ile birden çok araç için paylaşımlı kapasite yönetimi.

Bu yaklaşım, hem kullanıcı memnuniyetini artırmakta hem de işletmeciye abonelik ve kullanım tabanlı yeni gelir kanalları yaratmaktadır. Yakın vadede güvenli iletişim (TLS), daha geniş saha testleri ve ek OCPP işlevleri planlanmaktadır. Orta vadede paket depoları, lisanslama altyapısı; uzun vadede ise uzaktan güncelleme ve OCPP 2.0 geçişi öngörülmektedir.

**Keywords:** Elektrikli araç şarjı, Dinamik Yük Dengeleme, Katmanlı üyelik, Abonelik modeli, Banana Pi M2+, OCPP

[Abstract:0047] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# AI-Driven Smart Charging for Affordable and Sustainable EVs: A Scalable Model from India to Global Markets

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Overview
The rapid global adoption of Electric Vehicles (EVs) offers substantial opportunities for sustainable transportation but presents significant challenges to existing energy grid infrastructures. Unregulated EV charging can aggravate peak loads, cause grid instability, and increase reliance on non-renewable energy sources, thereby affecting grid reliability and the affordability of EV ownership. Smart charging, which flexibly optimizes charging schedules based on grid conditions and energy availability, is essential to address these issues. This paper presents a scalable AI-driven smart charging model designed to manage EV charging effectively across diverse grid stability environments. The system emphasizes integration of renewable energy and Vehicle-to-Grid (V2G) functionalities while adhering to Open charge point protocol (OCPP), advancing sustainability and affordability from emerging markets like India to broader global contexts.

Methodology
This proposed system is uniquely a multi-component AI system that can adapt to various grid conditions and optimize EV charging. An Artificial Neural Network (ANN) is used to manage grid stability, while a Deep Belief Network (DBN) is used for demand. To forecast the EV load for time series, a Long Short-Term Memory (LSTM) method is used. In this multi-component AI system, real-time dynamic charging schedule optimization is based on a reinforcement learning approach using Proximal Policy Optimization (PPO) to balance the usage of renewable energy, and optimize the Vehicle-to-Grid (V2G) dispatch.

The system is set up and tested in a discrete-event simulation built using SimPy. In addition to the operating model and AI architecture, the simulation environment also includes synthetic data generated to capture the variability associated with grid conditions and demand associated with EV charging, which was constructed to capture the transition in energy systems in India, with consideration for the large distribution of generation from diverse sources. To allow interoperability and secure real-time communication, the model supports Open Charge Point Protocol (OCPP) specification for EV chargers, and includes Internet-of-Things (IoT) monitoring modules.

RESULTS: Evidence of the AI-based smart charging framework is apparent in preliminary conceptual modeling and demonstrative simulations. From initial trials on simplified data, we see that primary AI models like ANN and DBN can learn and predict charging behavior accurately, with significantly high illustrative $R^2$ estimates (over 95%). Simulations provided initial evidence for expected consequences including a 18% reduction in charging costs, a 14% reduction in peak grid-load, and 65% of the charging demand fulfilled sustainably given renewable energy production. Taken together, the findings

indicate a high degree of promise that a shared AI optimization system that connects V2G intention and real-time renewably prioritized charging demand can improve on cost, grid-stability, and support sustainability.

CONCLUSIONS: This research presents a scalable and customizable AI-based smart charging framework that incorporates predictive analytics, reinforcement learning, and V2G technology in standardized communication protocols. The initial indicator suggests a reduction in costs, peak stress to the grid, and improved renewable energy integration across conditions on the grid. The next stages of research will focus on completing the entire SimPy simulation, robust model validation against different grid scenarios, and implementing a roll out to support the transition to cleaner energy and transport ecosystems across the globe.

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**Keywords:** Artificial Intelligence, Electric Vehicles, Smart Charging, Reinforcement Learning, Renewable Integration, Grid Optimization

**AuthorToEditor:** This submission presents an innovative AI-driven scalable smart charging model designed with emerging markets such as India in focus. The approach addresses critical challenges in integrating electric vehicles with renewable energy and grid stability. The findings have significant implications for sustainable and resilient energy transitions globally. Detailed methodology, comprehensive results, and practical applications will be fully elaborated in the full paper. This work offers valuable insights aligned with the conference’s goals of advancing clean energy and digital innovation.

[Abstract:0048] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Cybersecurity of EV-Chargers New Risks and Required Measures Under IoT Cyber Security Regulations

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Cybersecurity of EV-Chargers
New Risks and Required Measures Under IoT Cyber Security Regulations

Overview
Electric Vehicle Chargers (EV-Chargers) have evolved from being mere energy transfer devices into critical components of the smart energy ecosystem, thanks to their internet and cloud connectivity. These devices are now integrated with payment systems, energy management platforms, fleet solutions, and user mobile applications. However, this transformation has also made them prime targets for IoT-based cyberattacks.
The recently adopted Radio Equipment Directive Delegated Act (RED DA) and the Cyber Resilience Act (CRA) in Europe impose new obligations on EV-Charger manufacturers, not only regarding product safety but also concerning cybersecurity and lifecycle update management. This paper discusses the regulatory responsibilities EV-Charger manufacturers face and the technical and organizational steps required to meet them.

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Methodology
The EV-Charger ecosystem has been analyzed across three key layers:
1. Edge Devices: Hardware security, embedded software, cryptography, authentication.
2. Mobile Applications: User access control, authentication mechanisms, application security.
3. Cloud & Management Systems: Data protection, update management, threat monitoring.

Approach:
• Analysis of RED DA and CRA requirements.
• Modeling of potential attack scenarios (e.g., fake charging sessions, payment manipulation, DDoS attacks, grid intrusion through chargers).
• Evaluation of findings from cybersecurity testing processes such as penetration testing, security audits, and secure software development lifecycle practices.

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RESULTS: Key findings include:
• Non-compliance with regulations may block market access to the EU.
• Hardware requirements now include secure boot, HSM-backed cryptography, and secure firmware updates.
• On the software side, manufacturers are required to provide regular and secure updates to address vulnerabilities.
• Under CRA, discovered vulnerabilities must be reported to the European Union Agency for Cybersecurity (ENISA).

CONCLUSIONS: To ensure compliance and resilience, EV-Charger manufacturers must:
• Adopt a "Security by Design" approach from the earliest stages of development.
• Conduct regular penetration tests and security assessments both pre- and post-production.
• Deliver firmware updates securely and in encrypted form.
• Foster collaboration between manufacturers, software developers, and independent test laboratories to meet regulatory compliance.
At this point, CyberWhiz stands out as a strategic partner: providing end-to-end security solutions across edge devices, mobile applications, and cloud infrastructures. Working with many leading manufacturers in Türkiye, CyberWhiz offers integrated technologies, testing, and consulting services that enable EV-Charger producers to meet RED DA and CRA compliance requirements while gaining a competitive advantage in the global market.

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**Keywords:** IoT Cyber Security, RED DA, CRA, Penetration tests

[Abstract:0049] [Accepted:Oral Presentation] [Battery systems and technologies used in electric vehicles]

# Smart Integration of Active BMS and Multi-Level Converter: A Unique Topology for Enhanced AC-Battery System Control and Experimental Validation

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Overview
This paper introduces a multilevel converter (MLC)-based AC battery system designed to operate without a conventional inverter. The aim is to cut conversion losses, reduce cost, and avoid the weight and volume increases that are common in electric vehicles and stationary storage. Instead of relying on a separate inverter, the system generates AC directly through controlled switching of battery modules. This concept creates a lighter and more efficient alternative to existing solutions. In addition to the circuit innovation, the work discusses active balancing, thermal behavior, and Hardware-in-the-Loop (HiL) validation, offering a broad perspective on how the design performs in practice [1].

Method
The core idea is straightforward: battery modules are directly switched to form an AC output, so there is no inverter stage. By doing this, the number of components drops and the system becomes easier to cool and control. In the developed ACD-MLC circuit, only two switches are used per module, compared to the usual eight, which simplifies the hardware and control logic while lowering production costs. To keep cells balanced, an Active Battery Management System (BMS) was added. It monitors voltage, current, and temperature and actively shifts charge between cells through a multilevel DC converter. MATLAB/Simulink simulations tested switching strategies, while HiL experiments confirmed that the control runs reliably in real time. Thermal simulations were also carried out to check how heat spreads during high-power operation and to size the cooling system accordingly [2].

RESULTS: Testing shows that the system has clear benefits. With fewer switching devices, both conduction and switching losses are lower, which raises overall efficiency. The active BMS proved much more effective than passive balancing, cutting cell voltage deviations by over 90% and extending usable battery life. In HiL experiments, the control algorithm stayed stable even when loads changed suddenly. Simulations confirmed clean waveforms with low total harmonic distortion (THD). Thermal studies showed that the simplified design generates less heat, which reduces the need for heavy cooling hardware. When compared with conventional systems, the new setup delivered up to 2–5% higher efficiency, reduced volume by about 20%, and needed far fewer parts [3][4].

Implications
The findings indicate that direct switching combined with active balancing can change how future EVs and storage systems are built. Less complexity and lower cost make the design attractive for manufacturers, while reduced thermal stress helps improve long-term durability. The concept also works well with renewable generation and smart grids because AC can be supplied directly, avoiding extra conversion stages. Thanks to its modular nature, the system can be adapted for different applications from cars to residential backup to industrial storage. Although the current system already removes the inverter stage, further improvements could expand its role. A long-term vision is that this technology might take over both the battery and inverter functions in electric vehicles. In such a design, one integrated MLC-based AC battery pack would provide storage and drive the motor directly. That would cut system weight, lower cost, and improve driving range by reducing conversion losses. It would also simplify the vehicle's electrical architecture by merging the battery and power electronics into a single platform, while active balancing and thermal management would extend its service life. With these advances, the AC battery could evolve from being just an energy storage unit to becoming the central power electronics element of future electric vehicles.

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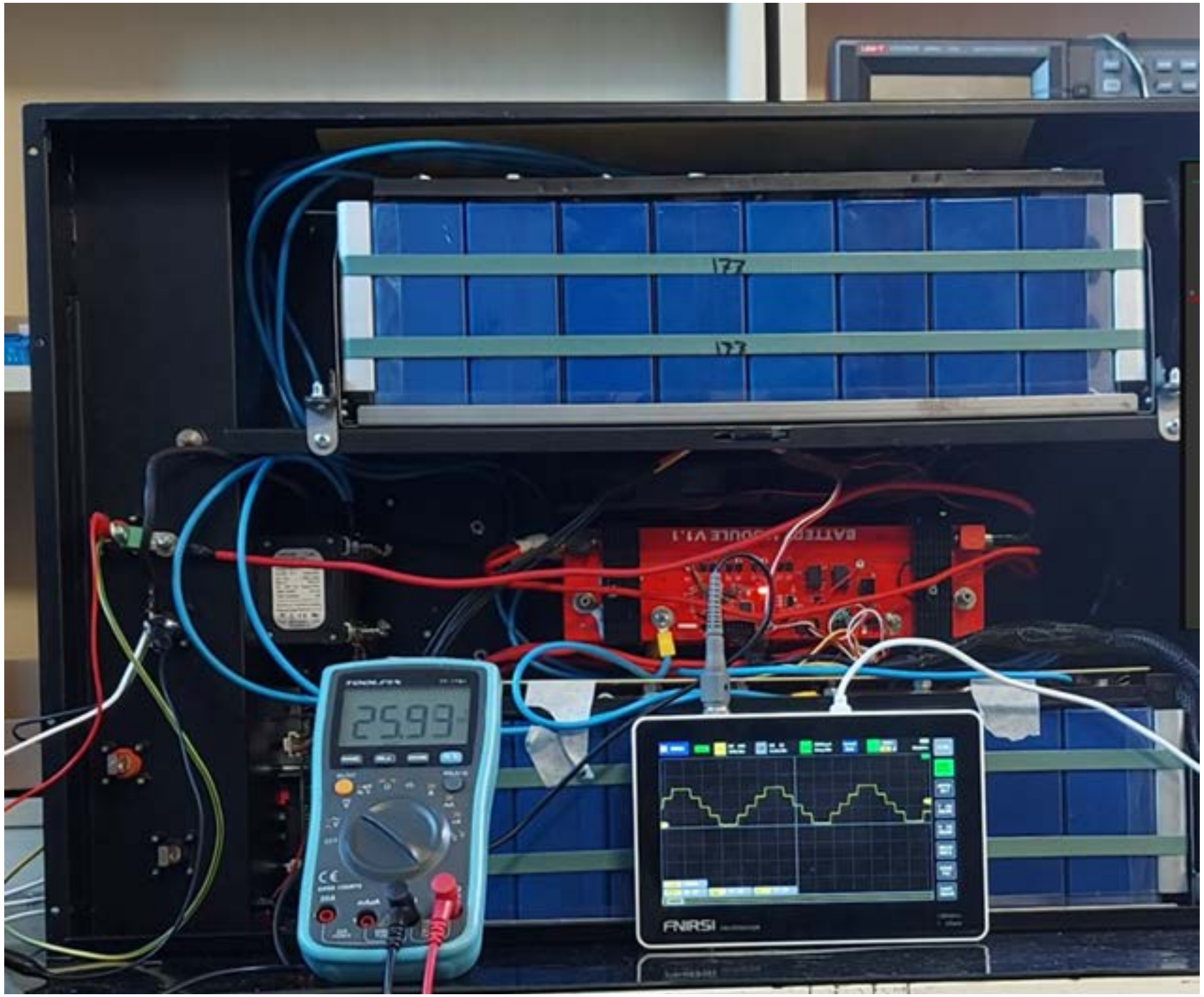
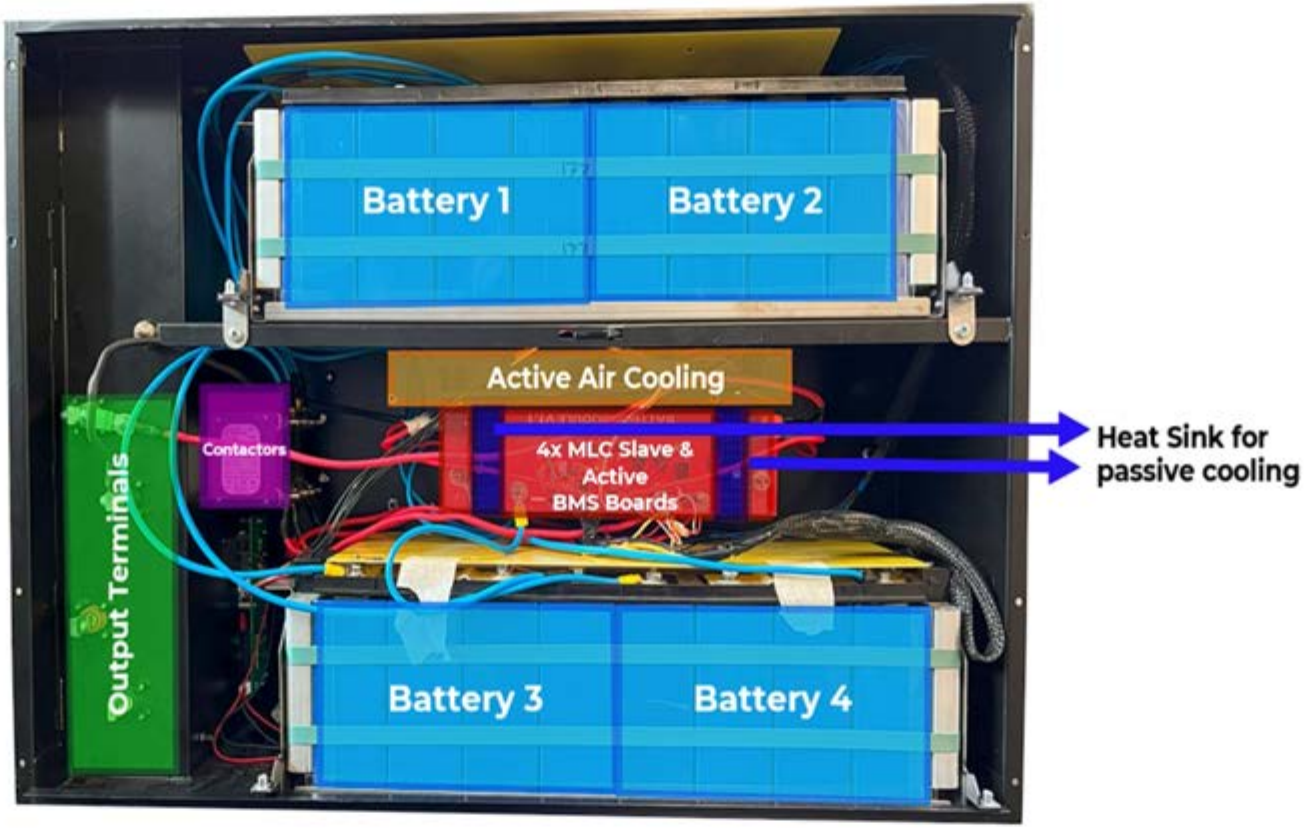
**Keywords:** Multi Level Converter, AC Battery, Active Balancing BMS, Battery Energy Storage System, Inverter, Electric Vehicle

**MLC Figure 1**




*The figure illustrates the HiL test results of the MLC system, showing the condition in which an AC output is achieved.*

**MLC Figure 2**




*The figure shows the sub-components that make up the AC Battery MLC System.*

[Abstract:0053] [Accepted:Oral Presentation] [New business models related to electric vehicles]

# Ad hoc payment systems and the future of open loops in EV charging

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Ad hoc payment systems and open protocols in shaping the future of EV charging ecosystem
The global expansion of electric vehicle (EV) charging infrastructure is not merely a technological challenge but a systemic transformation that touches on user experience, financial inclusion, regulatory frameworks, and digital interoperability. At the heart of this transformation lies the issue of accessibility and payment convenience. While the availability of charging stations continues to grow rapidly, the friction of requiring mobile applications, memberships, or closed ecosystems remains one of the biggest barriers to widespread EV adoption.

In response, the European Union's Alternative Fuels Infrastructure Regulation (AFIR) and the Turkish Energy Market Regulatory Authority (EPDK) have mandated the implementation of ad hoc payment systems. These systems allow EV drivers to initiate and complete charging sessions without pre-registration—directly through open loop payment channels such as credit and debit cards, NFC-based wallets (Apple Pay, Google Pay), or QR code solutions. As a result, charging points are evolving from basic energy delivery assets into integrated digital and financial service hubs, aligned with broader smart mobility and energy transition goals.

The evolution of payment systems illustrates the paradigm shift:
Closed loop systems, restricted to operator-specific cards or apps, provided data control and brand loyalty but created significant user barriers.
Open loop systems, based on banking and POS infrastructures, have enabled universal access, regulatory compliance, and improved user satisfaction.
The future vision lies in hybrid models where open loop payments are enriched with digital wallets, blockchain-based microtransactions, and tokenized carbon credits, allowing energy consumption to be linked with environmental value creation.

Alongside financial accessibility, open protocols are redefining technical and operational interoperability in the EV charging domain.
OCPP (Open Charge Point Protocol) has standardized communication between chargers and back-end systems, enabling hardware independence, smart charging, and ISO 15118-based Plug & Charge capabilities.

OCPI (Open Charge Point Interface) facilitates roaming and cross-network interoperability, allowing EV drivers to access multiple CPO networks with seamless authorization and settlement.

OCSC (Open Charging Station Controller), an emerging initiative, promises a more flexible and transparent approach to station-level management, particularly in multi-vendor environments, where device diversity and modular integration are key.

The debate between closed loop and open loop solutions is therefore not simply a technological choice but a strategic decision that will shape market dynamics. Operators favor closed loop for data control and customer retention, yet regulators and consumers increasingly demand open loop for inclusivity, transparency, and convenience. The most resilient business models are expected to combine both, providing users with multiple options while ensuring compliance with international and national regulations.

From a regional perspective, Turkey represents one of the most dynamic EV charging markets, with projections indicating over 200,000 new charging points after 2025. However, financing, location allocation, and integration remain major challenges. Innovative frameworks such as portal-based franchise systems, combined with bank-supported payment infrastructures, offer a pathway to scale. Solutions like EVSEPOS—a POS-based, ad hoc payment platform integrated with bank acquiring systems—illustrate how charging infrastructure can be democratized, offering direct credit card payments without operator-specific barriers, while also enabling advanced features such as invoice automation, carbon accounting, and tokenization (EVkWh).

Looking ahead, the convergence of ad hoc payment systems, open protocols, and digital finance will define the EV charging ecosystem. Charging stations will no longer be seen as isolated infrastructure assets but as nodes of a broader energy-finance-digital network, delivering not only electricity but also value-added services: carbon credit accumulation, loyalty rewards, and integration into smart grids and demand-response markets.
CONCLUSION: The future of EV charging depends on removing barriers to access and payment. By adopting open loop ad hoc systems, enforcing interoperability through OCPP/OCPI/OCSC, and integrating with fintech innovations, the industry can accelerate adoption, enhance user experience, and ensure sustainability. Turkey, with its regulatory alignment and ambitious infrastructure goals, is uniquely positioned to emerge as a regional leader in this transformation.

**Keywords:** ad hoc payment, open loop, OCPP, OCPI, interoperability, EV charging ecosystem

**AuthorToEditor:** We kindly request your valuable attention to this abstract, as it addresses one of the most critical challenges in the EV charging ecosystem: seamless ad hoc payment and open loop integration. EVSEPOS is the first and pioneering solution in Turkey that enables direct card payments at charging stations, fully aligned with EU AFIR and national EPDK regulations. By bridging open protocols (OCPP, OCPI, OCSC) with banking infrastructures, it represents not only a technological innovation but also a strategic milestone for the region’s sustainable mobility future. Given its novelty and relevance, we believe this work deserves priority consideration for presentation.

[Abstract:0054] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# A Modular, Real-Time Embedded Control Architecture for Autonomous Electric Vehicles Using STM32 and ROS2

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Overview
This work presents a modular, cost-effective control architecture for autonomous ground vehicles, designed to address the high complexity and cost of typical electronic systems. The proposed architecture uses a dual-processor approach: an STM32F407 microcontroller for low-level real-time control and a Raspberry Pi 5 with ROS2 for high-level decision-making and data processing. This division of tasks aligns with modern modular design practices, simplifying the intricate control and communication challenges inherent in autonomous vehicles [1][2].

Methodology
The system design integrates custom hardware, layered software, and robust power management.

1. System Architecture: A distributed control model was implemented. A custom-designed PCB housing the STM32F407 (running FreeRTOS) forms the hardware core, managing primary vehicle functions like propulsion, braking, and steering. A Raspberry Pi 5 (running ROS2 Humble) serves as the central decision-making unit, processing perception data and sending commands to the STM32 via a reliable I2C communication link.

2. Perception and Sensor Fusion: Environmental awareness is achieved via a multi-sensor suite, including a ZED 2i stereo camera, LiDAR, IMU, GPS, and ultrasonic sensors. Data is collected and synchronized within the ROS2 environment using the message_filters package to enable robust sensor fusion for a comprehensive understanding of the vehicle's surroundings.

3. Power Distribution and Management: The system is powered by a 72V, 30Ah Li-ion battery pack. A custom power distribution system utilizes DC-DC converters to provide stable 24V, 12V, and 5V outputs. A dedicated Battery Management System

(BMS) ensures operational safety by monitoring cell health and providing critical over/under-voltage and over-current protections [2].

RESULTS: Systematic validation confirmed the functionality of all hardware, including the custom STM32 control board, motor drivers, and converters. Oscilloscope tests verified the accuracy of STM32-generated PWM signals for precise motor control. The I2C communication link demonstrated a stable, low-latency data exchange between the processors, and all ROS2 topics operated correctly. The fully integrated system successfully executed basic autonomous functions (acceleration, braking, steering) in response to high-level commands. Fail-safe mechanisms and the power management system performed as designed throughout all tests.

CONCLUSIONS: This work successfully demonstrates a modular, cost-effective, and real-time control architecture. The key takeaway is that strategically delegating tasks between a low-level microcontroller and a high-level processing unit, integrated via a custom PCB, allows for the creation of a sophisticated and reliable autonomous system while managing complexity. This design serves as a valuable reference model for academic research and prototyping. Future work will focus on developing advanced sensor fusion algorithms, integrating machine learning models for path planning, and conducting comprehensive field tests to validate long-term reliability.

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**Keywords:** Autonomous vehicles, Modular control architecture, Sensor fusion, Real-time control, ROS2 / FreeRTOS integration

**AuthorToEditor:** This project introduces a modular and cost-effective control architecture for autonomous ground vehicles. I would like to thank the Scientific Committee for their time and evaluation.

[Abstract:0057] [Accepted:Oral Presentation] [Battery systems and technologies used in electric vehicles]

# Temperature-Accelerated Calendar Ageing of 18650 Li-Ion Cells: SoH Evaluation and Safety Assessment for EV Applications

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Calendar aging refers to the time-dependent degradation of lithium-ion batteries that occurs even without cycling. In electric vehicles (EVs), it critically affects the State of Health (SoH), which quantifies remaining capacity and performance. Calendar aging reduces SoH by decreasing capacity and increasing internal resistance, leading to lower driving range and peak power, and negatively impacting EV performance [1], [2]. The rate of degradation strongly depends on storage conditions, with elevated temperatures and high SOC accelerating parasitic reactions such as SEI growth and electrolyte decomposition [2], [3]. SoH deterioration also reduces vehicle residual value and may require earlier battery replacement. Accurate SoH assessment, considering both calendar and cycle aging, is essential for warranty, maintenance, and lifetime cost estimation [3], [4]. Modern BMS incorporate SoH models accounting for calendar aging to predict degradation, optimize charging, and enhance battery longevity [4]. Calendar ageing in Li-ion batteries refers to the irreversible performance degradation that occurs over time while the cell is at rest, without cycling. It is driven mainly by storage temperature, SOC, and duration, and involves side reactions such as SEI growth, electrolyte decomposition, and gas formation, leading to increased internal resistance and reduced capacity [5–7].

For the calendar ageing experiments, commercial 2800 mAh (Aspilsan) and 2500mAh (Samsung) 18650 lithium-ion cells were first charged to 4.2 V using a constant-current–constant-voltage (CC–CV) protocol at a rate of 1C. After charging, the cells were placed into a temperature-controlled oven and stored at 50 °C for one week. At the end of the storage interval, the cells were removed from the oven and allowed to cool to ambient temperature for 24h. Subsequently, electrochemical impedance spectroscopy (EIS) and energy throughput (Wh) measurements were carried out to characterize degradation effects. In addition, open-circuit voltage (OCV), internal resistance (R_int), charge/discharge capacity (Ah), and peak power capability were recorded. The cells were then recharged to 4.2 V at 1C using the same CC–CV protocol, followed by another one-week storage interval under identical conditions. This sequence of full charging → storage at 100% SOC → characterization was repeated in order to impose calendar ageing at 100% SOC, enabling the study of time- and temperature-dependent degradation under high-SOC stress, while providing quantitative data for SoH prediction. During the storage period, flammable gas formation due to electrolyte decomposition or cell venting was monitored and recorded using Hydrogen ($H_2$), Carbon monoxide (CO), carbon dioxide ($CO_2$), and Volatile organic compounds (VOC) sensors. These sensors ensure early detection of unsafe conditions during high-SOC, high-temperature calendar ageing experiments.The results demonstrate that high-SOC calendar ageing significantly impacts 18650 Li-ion cell SoH, emphasizing the need for optimized storage and monitoring strategies to ensure reliable performance and longevity in electric vehicle applications.

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**Keywords:** Calendar aging, battery, SoH, SoC

[Abstract:0061] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# Autonomous EV Charging Grid: AI-Driven Decentralized Energy Marketplace

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The rapid growth of electric mobility poses significant challenges to existing charging infrastructures, including grid instability, peak demand stress, and the underutilization of renewable energy resources. Current smart charging solutions focus on load management at a local level, but lack a holistic approach to energy distribution and value creation within the charging ecosystem.

This project proposes the Autonomous EV Charging Grid (AECG), an AI-driven decentralized energy marketplace that transforms EV charging stations into dynamic energy hubs. Each station operates not only as a consumer but also as a producer and distributor, capable of storing surplus renewable energy and trading it with nearby stations, the central grid, or directly with electric vehicles. By leveraging artificial intelligence for demand forecasting, dynamic pricing, and carbon-aware optimization, the system ensures efficient energy utilization and reduced carbon footprint.

The marketplace is secured with blockchain technology, enabling transparent, real-time energy transactions between stakeholders. Electric vehicles themselves become active participants, selling energy back into the network during peak demand, thereby turning mobility assets into mobile storage units.

The proposed solution addresses critical industry pain points: lowering operational costs for charge point operators, improving user affordability, enhancing grid resilience, and accelerating the integration of renewable energy. With its decentralized structure and sustainability-focused model, AECG represents a transformative step toward the future of e-mobility, where charging networks evolve into intelligent, self-optimizing energy ecosystems.

**Keywords:** Autonomous EV Charging, Decentralized Energy Marketplace, Artificial Intelligence (AI), Dynamic Pricing, Blockchain Energy Trading, Carbon-Aware Optimization

**AuthorToEditor:** This proposal aims to contribute not only to the advancement of e-mobility infrastructure but also to the broader vision of decentralized, carbon-aware energy systems. The Autonomous EV Charging Grid represents a convergence of AI, blockchain, and sustainable energy management, designed to address real-world operational and environmental challenges. We look forward to receiving your feedback and guidance on refining this concept toward practical implementation.

[Abstract:0068] [Accepted:Oral Presentation] [Battery systems and technologies used in electric vehicles]

# Hyperparameter optimized comparison of rnn gru and lstm models for battery remaining useful life prediction

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Accurate estimation of the remaining useful life (RUL) of lithium-ion batteries is critical for maintaining the safe, reliable, and cost efficient operation of electric vehicles and energy storage systems. Different battery metrics provide important information for assessing battery condition. Battery degradation shows strong temporal dependencies and nonlinear patterns. Consequently, recurrent neural network (RNN) architectures, including gated recurrent units (GRU) and long short-term memory (LSTM), are widely used for battery life prediction. This study systematically compares RNN, GRU, and LSTM models, with each model optimized using random search and Bayesian optimization.

The dataset comes from controlled cycling experiments by HNEI on 14 NMC-LCO cells. Each cell went through more than 1,000 charge–discharge cycles at 25°C. The protocol used constant current charging (CC-CV) at C/2 and 1.5C discharging. The preprocessed dataset represents each cycle as one row. Engineered features include charge–discharge ratio, differential voltages, voltage change rates, and temporal degradation indicators. The charge and discharge ratio is important because it can suggest variations in signal capacity imbalances. These can indicate issues with lithiation or delithiation in the battery. Differential voltage analysis reveals shifts in electrochemical processes or phase change. These shifts may indicate a decline in performance or degradation. Feature selection lets models reduce redundancy and improve interpretability. Pearson and Spearman correlation, mutual information, recursive feature elimination, and Shapley Additive Explanations (SHAP) were used in feature selection. All feature selection methods selected their features using the voting method. Those that received votes from all methods were used in model training.

Hyperparameter optimization was carried out using a combination of two approaches, one of which is random search over parameter grids and Bayesian optimization with a tree-structured Parzen estimator in Optuna. Model selection was based on the mean absolute error. Random Search tries to find the best point by starting from 20 different random points. After an initial exploration, The Tree-structured Parzen Estimator then takes over and separates the best trials (low val_mae) from the bad trials (high val_mae). It compares the parameter distributions of the good trials with the distributions of the bad trials. Then, when selecting parameters for new trials, it prioritizes combinations similar to the good trials. In other words, the search is no longer random but guided by the learned distribution.

The search space included learning rates from $5 \times 10^{-5}$ to $5 \times 10^{-4}$, hidden units from 64 to 256, dropout rates from 0.2 to 0.5, and batch sizes from 32 to 64. Models were trained using the TensorFlow library with the Adam optimizer, Huber loss, and gradient clipping. Early stopping was implemented to prevent overfitting.

Model performance was assessed using Leave-One-Battery-Out Cross-Validation. Each of the 14 batteries was used as a test set, while the remaining ones served as training data. Final performance metrics were averaged across all folds. This approach provides a very strict assessment of generalization to unseen batteries. The LSTM model had the lowest mean absolute error (MAE: 3.7040) and root mean square error (RMSE: 4.9140). GRU followed with MAE: 3.9631 and RMSE: 5.7337. The conventional RNN showed higher errors (MAE: 4.7352, RMSE: 6.0192). LSTM produced the most accurate predictions. The GRU showed competitive performance with less parameters and faster prediction, making it suitable for real time and embedded applications.

These findings show two key insights. First, GRU and LSTM architectures outperform conventional RNNs. This emphasizes the importance of advanced gating mechanisms for analyzing battery degradation. Second, while LSTM achieves the highest accuracy, GRU offers a good balance of accuracy and efficiency. Its simpler structure and faster prediction make GRU suitable for embedded or real-time applications.

**Keywords:** Lithium-ion battery, Remaining useful life (RUL) prediction, Recurrent neural networks (RNN), Long short-term memory (LSTM),Gated recurrent unit (GRU),Hyperparameter optimization

**AuthorToEditor:** We would like to explore potential journal extensions of our submission.

[Abstract:0071] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Shared Charging Sustainable mobility for all.

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This enthusiastic talk will present the Vision of The Shared Charging Project

Funded by the Climate and energy-fund of the Austrian ministry of Innovation, Mobility and Infrastructure.

The idea is to promote and support fully electrified personal mobility, while relying entirely on renewable energy, adaptive, efficient and accessible charging infrastructure is key. This project aims to develop and demonstrate a novel approach to shared charging infrastructure systems that seamlessly integrates renewable energy sources. By leveraging cutting-edge technologies and innovative business models, we seek to create a sustainable, cost-effective, and widely available charging network that accelerates the transition to clean transportation.

The rapid adoption of electric vehicles presents both opportunities and challenges for the energy sector. While EVs offer significant environmental benefits by reducing greenhouse gas emissions, their increasing popularity also places new demands on the electrical grid. Simultaneously, the growing penetration of renewable energy sources like solar and wind power creates a unique opportunity for synergy between clean energy generation and EV charging. This project will explore and develop solutions that capitalize on this synergy, addressing key concerns such as reducing carbon footprint and enhancing grid stability through smart charging and energy storage solutions.

Our comprehensive approach encompasses several critical components. The project team will conduct thorough modelling and concept assessment to identify the most promising strategies to lower the grid strain caused by BEV charging. This emphasizes evaluating solar and its potential implementations in different geographical contexts.

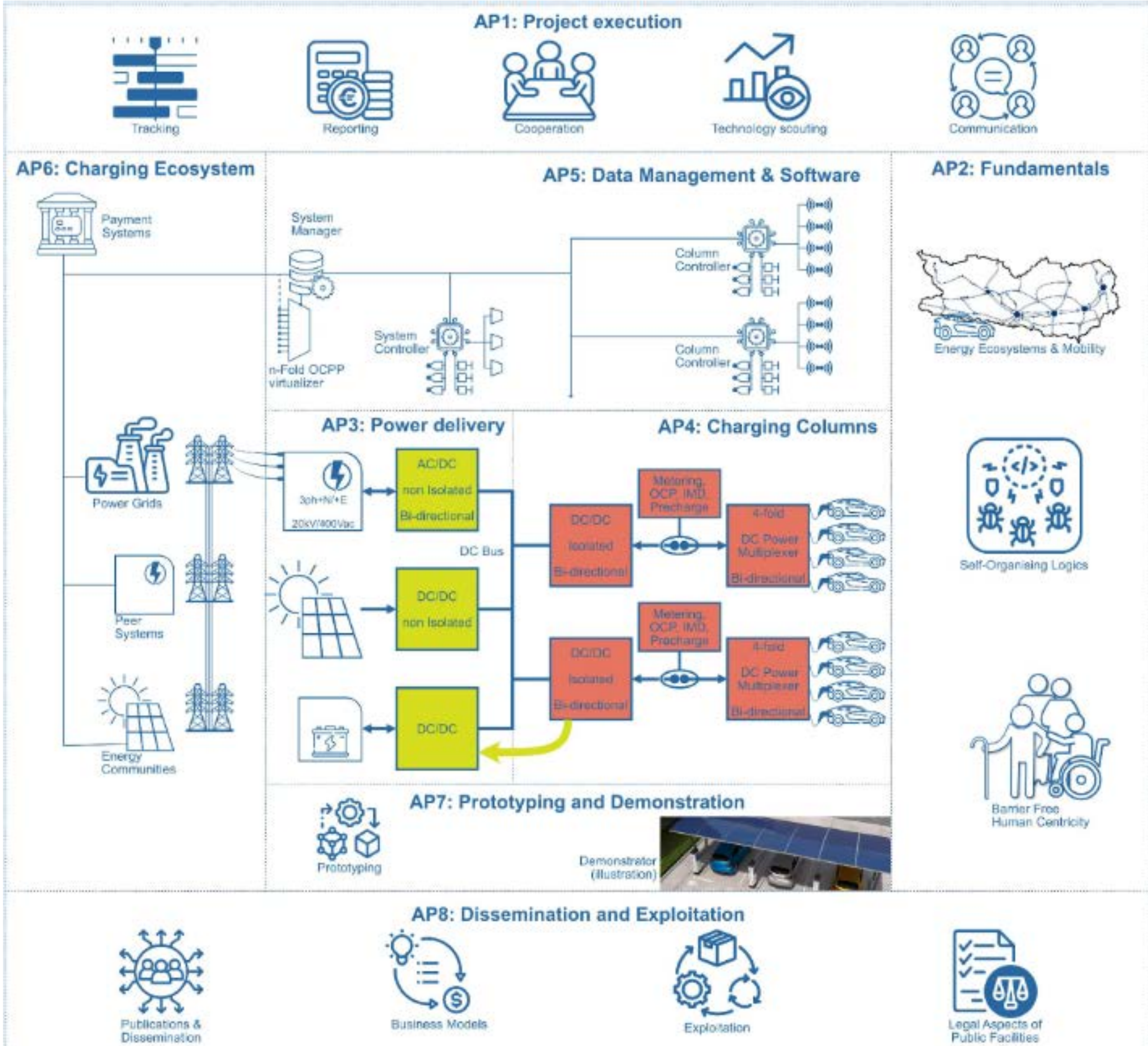
Next, we will focus on user inclusive technology development, leveraging advancements in ergonomics and User-Centric-Design. The resulting system must be truly accessible for everyone to allow widespread adoption. The project will then move into developing, prototyping and demonstrating high efficiency energy distribution microgrid systems. We will build and test working models of our integrated renewable energy EV charging systems. The demonstrator prototypes will be deployed in an urban workplace where it is evaluated for performance and user acceptance under real-world conditions. Crucially, we recognize that the success of this initiative depends not only on technological innovation but also on developing viable business models. Efforts will be dedicated to exploring and refining business strategies that can make renewable-powered EV charging stations economically sustainable and attractive to both operators and users.

By addressing the entire ecosystem of renewable energy integration with EV charging – from concept to implementation to business viability – this project aims to pave the way for a future where electric vehicles are powered exclusively by clean, renewable energy. Our work will not only contribute to reducing transportation-related emissions but also demonstrate how the challenges of intermittent renewable energy generation can be turned into opportunities through smart integration with EV charging infrastructure.
Ultimately, we envision a network of charging stations that are as ubiquitous and user-friendly as today's gas stations, but with the added benefit of being powered by the sun, wind, and other renewable sources, making clean and sustainable personal mobility a reality for all.

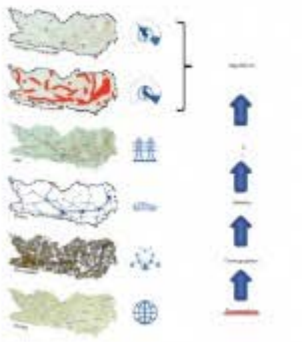
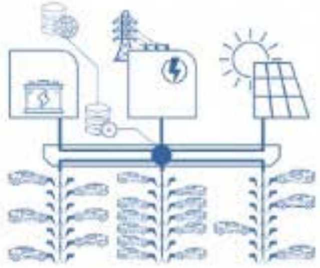
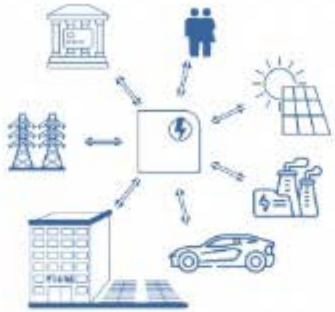
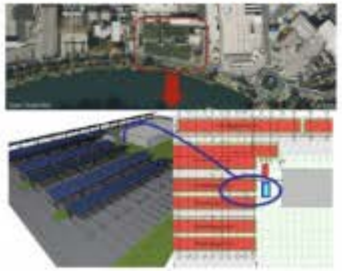
The talk will inspire to think different and out of the box for a good transition into a green future.

**Keywords:** Sustainable Mobility, Smart Charging, Cost effective, Digital Energy Sandbox, Novel Dynamic and Shapeless Swarm,

**Project Overview**



**Project Phases**

| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| Simulation and modelling | System Development | Infrastructure Integration | Demonstration | Business Models |

[Abstract:0080] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# Fire safety measures for electric vehicles and charging units

Sedat Akıncı
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With the rapid increase in the number of Electric Vehicles (EVs) and the widespread installation of charging units, the risk of EV-related fires is also rising. Numerous EV fire incidents recorded both globally and in our country have demonstrated that catastrophic outcomes are possible.

In addition to individual EV users, many companies are now building new fleets with EVs and installing dedicated charging units at their headquarters and facilities. Residential charging unit installations are also growing steadily. However, as these charging units expand in an uncontrolled manner, without clear reference to specific rules, standards, or installation guidelines, the associated fire risks continue to escalate.

EV battery fires differ significantly from conventional fires due to their chemical nature, requiring distinct firefighting and intervention methods. Research and trials on how to effectively manage EV fires are ongoing worldwide.

Both fixed and portable extinguishing systems, their correct application, and the necessary preventive measures must be clearly communicated to individual users and corporate operators. Trade fairs and exhibitions serve as important platforms to raise awareness and disseminate fire safety knowledge.

The presentation will:

Provide examples of EV fire incidents from both global and local contexts.

Highlight essential preventive measures to reduce EV fire risks.

Explain strategies for controlling EV fires in cases where preventive measures prove insufficient.

**Keywords:** fire, battery, EV, charge, prevention

[Abstract:0081] [Accepted:Oral Presentation] [Other topics related to electric vehicles]

# How The Operating Strategies Of The BakuBus Electric Bus Fleet That Are Capable Of Charging Hundreds Of Buses Per Night Are Consistent With World Best Practices For Efficiency, Reliability, And Sustainability And May Evolve By 2030

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*Overview*

The electrification of public transportation has become a cornerstone in achieving sustainable urban mobility and reducing greenhouse gas emissions. One of the most critical components of this transition is the establishment of reliable, efficient, and safe energy charging infrastructure for electric bus fleets. In the South Caucasus, “BakuBus” operates the largest electric bus fleet, positioning Azerbaijan as a regional leader in sustainable transit solutions. This study examines the development and management of BakuBus' energy charging stations, with particular emphasis on safety standards, optimized station location planning, and ensuring operational smoothness in daily transport schedules. Comparative insights from international practices are incorporated to contextualize BakuBus' approach within the global shift toward low-emission mobility.

Currently, "BakuBus" manages a fleet of 1,124 electric buses, transporting hundreds of thousands of passengers every day. Each night, these buses undergo rapid charging that takes only a few hours, allowing the entire fleet to return to service seamlessly the following morning. This efficient cycle not only guarantees smooth public transport operations but also highlights Azerbaijan’s commitment to integrating advanced green mobility solutions on a national scale. In addition, this study examines how world’s best practices of ensuring efficiency, reliability, and sustainability at a mass-scale operating electric bus operations are reflected in the operating practices of “BakuBus” electric bus fleet that has the capability of recharging hundreds of buses during a night shift and how those are likely to evolve by 2030.

*Methodology*

*Literature Review*: Systematic literature of research of business and academic sources of mass-scale electric bus operations has been conducted. Peer-review journals, global electric bus fleet studies, and technical articles on standards of charging infrastructures were utilized as sources. They established a benchmarking foundation of efficiency standards, operational reliability indicators, and sustainability practices.

*Operational Data Analysis*: Quantitative "BakuBus" operating data like bus schedules, charging station throughput, energy utilization patterns, and fleet utilization were extracted from "BakuBus" operating reports. Performance indicators and statistical methods were applied to investigate reliability and efficiency of night-time recharge and fleet deployment as a system.

*Fleet Observations and Visits*: Site visits were conducted at 4 "BakuBus" garages and over 280 charging stations in order to analyze infrastructure configuration, real-time operating flows, and safety measures. Note was taken of capacity control at stations, bus turnaround effectiveness, and schedule coordination of charging and routes.

*Benchmarking Against Best Practices Worldwide*: BakuBus' operations were benchmarked using international standards and practices of electric bus fleets from cities across Europe, Asia and America. They involved sustainability practices, maintenance techniques, fleet reliability, energy efficiency, and charging technologies.

RESULTS: Charging station configurations are precisely optimized for high throughput while simultaneously allowing multiple buses to charge while strictly requiring tight safety standards equivalent to higher than industry leaders. Additional findings document that route optimization, vehicle deployment, and energy usage are unified while minimizing consumption while preventing operational disruptions. Benchmark comparison results recognize that BakuBus's use of advanced charging systems, integrated central control platforms, and predictive maintenance matches approaches taken by world-leading electric bus fleets. A stepwise expansion strategy sees an addition of an extra 200 buses at the depots per annum toward the year 2028. Further, from the current year onward, production of eco-buses will also commence at the Sumgayit Industrial Park within Azerbaijan while locally manufacturing the 9- and 12-meter variants while having an annual production of 500 buses. Scenario analysis extending out toward the year 2030 reveals that continued expansion of fleets of buses, addition of sources of renewable energy, while installation of higher-capacity fast-charging stations will improve efficiency while also environment-related performance. Overall results show that BakuBus not only embodies today's best practices but also is strongly placed toward the next steps toward more sustainable/resilient large-scale electric bus operations.

CONCLUSIONS:
BakuBus' electric bus fleet aligns with global best practices in efficiency, reliability, and sustainability. Overnight charging of hundreds of buses, optimized station layouts, and strict safety ensure seamless service. Expanding infrastructure, renewable energy, and predictive maintenance will drive growth and resilience through 2030.

**Keywords:** BakuBus, electric bus, charging station, bus fleet, sustainability

**Bus Fleet**

**Bus Fleet**

**Charging station**

**Ecobus**

**BakuBus LLC's electric bus garages**

| Garages | The number of Ecobuses | The number of charging stations | Transformer Substation (MVA) |
|---|---|---|---|
| Park 3 (Zigh garage) | 210 | 60 | 2*16 |
| Park 4 (Albalilig garage) | 167 | 42 | 2*13 |
| Nakhchivan | 72 | 16 | 6*2.5 |
| Khirdalan | 320 | 80 | 2*20 |
| Liberated regions | 355 | 67 | 4*(2*1.25)<br>4*(2*1.6)<br>2*(2*2)<br>1*(2*4)<br>1*(2.7) |
| Total | 1124 | 295 | 2*60.6 |

[Abstract:0089] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Elektrikli Araç Dönüşümünde Kullanıcı Deneyimi ve İhtiyaca Yönelik Özelleştirmeler

Mehmet Burak Demirtaş
WAT Mobilite

Elektrikli araç dönüşümü günümüzün en önemli teknolojik ve toplumsal değişimlerinden biridir. İnsanlığın yaklaşık yüz yıl önce yaşadığı motorlu araç devriminden sonra ikinci kez ulaşım alışkanlıklarımız kökten değişiyor. O dönemde at arabaları, bisikletler ve toplu taşıma araçları şehirlerin kalbinde yer alırken, benzinli otomobilin yaygınlaşması hem kentlerin hem de bireylerin yaşam biçimini dönüştürdü. Bugün benzer ölçekte bir değişim elektrikli araçlarla birlikte yaşanıyor. Bu dönüşüm yalnızca motor teknolojisinin değişmesi değil; enerji, çevre, ekonomi, şehir planlaması ve bireysel tercihleri kapsayan bütünsel bir paradigma kaymasıdır.

Elektrikli araçların yaşamın akışına etkisi giderek daha fazla hissediliyor. Öncelikle toplumsal algıda bir dönüşüm söz konusu. Artık bir araca sahip olmak yalnızca ulaşım ihtiyacını karşılamaktan ibaret değil; çevreye duyarlılık, teknolojiyi benimseme ve sürdürülebilir bir yaşam tarzı ile özdeşleşiyor. Elektrikli araç kullanan bireyler, sessiz sürüşün verdiği huzuru, düşük bakım ihtiyacının kolaylığını ve dijital özelliklerin sunduğu kişiselleştirilmiş deneyimi yaşamlarına entegre ediyorlar. Bunun yanı sıra, şehirlerde şarj istasyonlarının yaygınlaşması yeni sosyal davranış kalıpları oluşturuyor. İnsanlar alışveriş merkezlerinde, otoparklarda ya da iş yerlerinde araçlarını şarj ederken zamanlarını farklı biçimlerde değerlendirmeye başlıyorlar.

Ekonomik açıdan bakıldığında, elektrikli araç devrimi küresel rekabeti yeniden şekillendiriyor. Batarya üretimi, enerji depolama çözümleri ve yazılım geliştirme, otomotiv sektöründe yeni liderlik alanları yaratıyor. Bir yandan geleneksel yan sanayi daralırken, diğer yandan milyonlarca kişiye yeni iş fırsatları sunuluyor. Devletler, elektrikli araçların yaygınlaşmasını teşvik etmek için vergi indirimleri, sübvansiyonlar ve altyapı yatırımlarına hız veriyor. Bu da ülkeler arasında teknoloji üstünlüğü ve stratejik kaynak rekabetini artırıyor. Kim batarya teknolojisinde daha verimli ve sürdürülebilir çözümler geliştirirse, geleceğin otomotiv pazarında söz sahibi olacak.

Çevresel etkiler ise dönüşümün belki de en güçlü motivasyonu. Fosil yakıtlı araçların neden olduğu karbon salımı, şehir içi hava kirliliği ve gürültü sorunları, elektrikli araçlarla büyük ölçüde azaltılabiliyor. Ancak bu sürecin başarıya ulaşması için enerji üretiminde yenilenebilir kaynaklara yönelmek kritik. Aksi halde, kömürle üretilmiş elektrikle çalışan araçlar çevresel faydayı sınırlı kılacaktır. Ayrıca kullanılmış bataryaların geri dönüşümü, hem çevre kirliliğinin önüne geçmek hem de lityum, kobalt gibi stratejik madenlerin tekrar kullanılabilmesi açısından büyük önem taşıyor.

Teknolojik boyut da dönüşümün merkezinde yer alıyor. Elektrikli araçlar, tekerlekleri olan bilgisayarlar gibi çalışıyor. Araç içi yazılımlar sayesinde sürüş deneyimi sürekli güncellenebiliyor, güvenlik artırılabiliyor ve kullanıcı ihtiyaçlarına göre kişiselleştirilmiş çözümler sunulabiliyor. Hızlı şarj teknolojilerindeki ilerlemeler menzil kaygısını azaltırken, kablosuz şarj ya da batarya değişim istasyonları gibi yenilikçi çözümler geleceğin standartlarını belirleyebilir.

Son kullanıcı açısından bu dönüşüm, yaşamın akışında yeni alışkanlıklar doğuruyor. Artık aracın yalnızca bir ulaşım aracı değil, kişisel yaşam tarzının bir uzantısı olduğu görülüyor. Yazılım güncellemeleriyle yeni özellikler kazanmak, sürüş konforunu artırmak ve çevreye duyarlı bir yaşam tarzını benimsemek bireylerin değer dünyasına da yansıyor.

Geleceğe bakıldığında ise elektrikli araçların yalnızca ulaşım alışkanlıklarını değil, tüm mobilite anlayışını dönüştüreceği görülüyor. Otonom sürüş teknolojileri, akıllı şehir altyapıları ve araç paylaşım platformlarıyla birlikte bireysel araç sahipliği azalabilir; mobilite bir hizmete dönüşebilir. Ayrıca elektrikli araçların enerji ekosistemine entegrasyonu sayesinde, araçlar yalnızca enerji tüketicisi değil, aynı zamanda enerji sağlayıcısı haline gelebilir. Evlerde veya iş yerlerinde şebekeye bağlı araçların gerektiğinde enerji geri verebilmesi, geleceğin enerji yönetiminde devrim yaratacaktır.

Sonuç olarak, elektrikli araç dönüşümü yalnızca otomotiv endüstrisinin bir yeniliği değil, tüm toplumsal yaşamın kökten yeniden yapılanmasıdır. Tarihin akışını değiştiren otomobil devriminden sonra şimdi ikinci büyük dönüşümün eşiğindeyiz. Bu dönüşüm, yaşamın her alanına dokunarak bireylerin, şehirlerin ve küresel sistemlerin geleceğini yeniden tanımlıyor.

**Keywords:** transformation, electrification, Fleets, Shared charging,en-route, destination charging

[Abstract:0090] [Accepted:Oral Presentation] [Electric vehicle charging and smart charging technologies]

# Advances in bidirectional on-board chargers for next-gen EVs and V2X applications

Julia Luechinger
Julia Luechinger

Presentation Synopsis
The rapid evolution of electric vehicles (EVs) and vehicle-to-everything (V2X) technologies demands high-efficiency, compact, and intelligent charging solutions. The BRUSA HyPower bidirectional on-board charger "OBC7" enables seamless energy transfer between EVs, the grid, and other DC sources, supporting both charging and discharging functionalities.

Key Discussion Points

• Technology breakthroughs:
o High-efficiency topologies leveraging wide-bandgap semiconductors (SiC/GaN) and advanced thermal management.
o Modular and scalable designs for flexible integration across EV platforms.
• Grid integration & V2X capabilities:
o Role of bidirectional on-board chargers in V2G (Vehicle-to-Grid), V2H (Vehicle-to-Home), and microgrid stabilization.
o Standards-compliance and interoperability challenges.
• Intelligent control and safety:
o Adaptive digital control strategies for dynamic load balancing and power factor correction (PFC).
o Critical safety considerations: fault tolerance, EMI/EMC, and cybersecurity in on-board charging systems.

**Keywords:** bidirectional, on-board charger, V2X applications

[Abstract:0099] [Accepted:Oral Presentation] [Battery systems and technologies used in electric vehicles]

# Astrosit: AI-Based Gas Detection for Electric Vehicle Battery Safety

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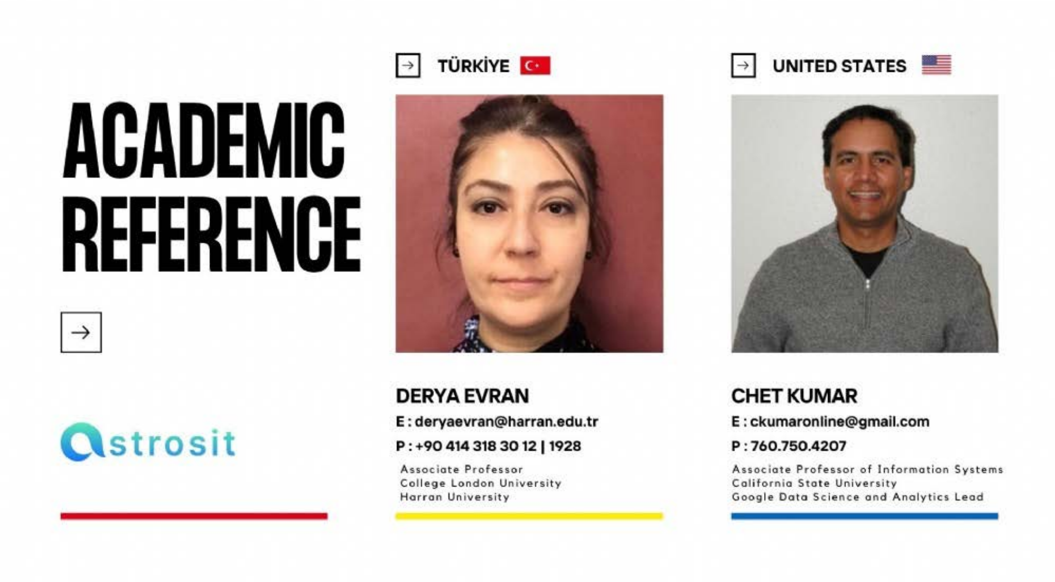
[4]California State University, Department of Information Systems, California, United States

The global electric vehicle (EV) and energy storage industry is undergoing explosive growth, with the EV market projected to surpass 45 million units annually and the battery sector exceeding $150 billion by 2030. However, this rapid expansion exposes major safety challenges — particularly thermal runaway, a dangerous chain reaction within battery cells that causes gas emissions, overheating, and fires. Each year, over 2,000 EV-related battery fires are reported worldwide, leading to $80 billion in economic losses, along with millions in environmental damage and recall costs. According to the World Health Organization (WHO), toxic emissions and industrial gas leaks contribute to 7 million premature deaths annually. Studies reveal that nearly 15% of all energy-related incidents originate from the undetected accumulation of hazardous gases such as hydrogen ($H_2$), methane ($CH_4$), carbon monoxide (CO), carbon dioxide ($CO_2$), acetylene ($C_2H_2$), ethylene ($C_2H_4$), sulfur hexafluoride ($SF_6$), and volatile organic compounds (VOCs). These gases are key precursors to internal battery failures and external fire outbreaks in vehicles and stationary storage systems. Astrosit has been designed to eliminate this hidden risk through a combination of nanotechnology, AI analytics, and real-time monitoring. At its core lies a carbon nanotube (CNT)-based nanohybrid sensor chip, uniquely engineered for multi-gas detection and long-term stability in battery environments. Initially non-conductive, the chip is chemically functionalized to become sensitive to specific gas molecules, responding to their interactions through conductivity shifts across a 16-electrode array. Each module houses four CNT chips, providing 64 independent sensing channels, each capturing fine variations in the electrical signal. Every 1.8 seconds, a full scan cycle is completed, recording 64 conductance values plus temperature and humidity readings, yielding 66 parameters per data frame. Over time, these measurements build a dataset of around 6,000 values per gas type, which are encoded in ASCII format for transmission through UART, SPI, or BLE protocols. The power efficiency of the Astrosit chip is remarkable — consuming only 0.000001 W, powered by a 3.7 V 45 mAh cell, ensuring weeks of autonomous operation. Its embedded microcontroller preprocesses raw signals using noise filtering, baseline normalization, and drift correction before AI analysis. The data are then processed by a hybrid machine-learning model combining Convolutional Neural Networks (CNN) for temporal pattern extraction, Random Forest for high-dimensional classification, and XGBoost for adaptive probability scoring. The AI continuously retrains itself on incoming field data, improving prediction accuracy with every cycle. Astrosit's software visualizes emissions and anomalies via heatmaps, risk meters, and real-time concentration plots, allowing operators to intervene before a runaway reaction begins. The system has demonstrated >98% detection accuracy and response times under 2 seconds, remaining reliable from −20°C to +70°C and 20–90% relative humidity. This performance makes it uniquely compatible with battery packs, EV charging stations, and energy storage facilities, providing constant monitoring where conventional sensors fail. All these innovations are consolidated under patent number TURKPATENT 2025-GE-179248, protecting the nanohybrid design and multi-

electrode detection structure. Beyond real-time safety, Astrosit contributes to the creation of Turkey's first digital gas and odor database, recording unique sensor patterns for each detected gas to enhance future AI training. In essence, Astrosit is not just a sensor — it is a complete AI-driven safety ecosystem. By identifying gas emissions minutes before ignition thresholds, it prevents costly shutdowns and environmental damage, reduces maintenance costs, and extends battery life. This nanohybrid approach enables manufacturers to meet increasingly strict safety standards across the US, Europe, China, and Turkey, regions driving the electric mobility revolution. Combining precision nanomaterials, ultra-low-power electronics, and real-time analytics, Astrosit sets a new benchmark for battery safety, ensuring that the global transition to electrification is not only efficient but also safe, predictive, and sustainable.Astrosit’s next phase focuses on scalability and integration within global EV manufacturing ecosystems. The system’s modular design allows seamless adaptation to diverse battery chemistries such as LFP, NMC, and solid-state architectures, while its cloud-based analytics supports fleet-wide predictive maintenance. By merging sensor intelligence with industrial IoT frameworks, Astrosit transforms energy infrastructure monitoring into a data-driven, self-learning safety network that strengthens the reliability of future electric mobility worldwide.

**Keywords:** Carbon Nanotube-Based Sensing, Thermal Runaway Mitigation, Advanced Battery Diagnostics, Electric Vehicle Energy Systems, Nanohybrid Sensor Architecture, Real-Time Predictive Analytics

**Academic References**




*Official academic references of the Astrosit project. Prof. Derya Evran (Harran University, Türkiye) and Prof. Chet Kumar (California State University, USA) have provided academic guidance and technical validation throughout the research and development stages.*

**photo_1**


*Early-stage PCB layout and 3D modeling of the Astrosit nanohybrid gas-sensing module showing multi-layer circuit integration.*

**photo_2**

*On-site testing conducted in controlled industrial conditions to evaluate sensor stability and data transmission.*

**photo_3**


*Bench experiments performed with $NH_3$ and $H_2S$ gases to validate sensor selectivity and calibration accuracy.*

**photo_4**

PATENT BAŞVURUSU

| | | | |
|---|---|---|---|
| Tahakkuk No | 3464148 | Başvuru Numarası | 2025/003272 |
| Evrak Numarası | 2025-GE-179248 | Evrak Tarihi | 19.03.2025 10:59:35 |
| Erken Yayın Talebi | Hayır, başvurum 18 aylık süre dolduktan sonra yayınlansın. | Başvuru ile Birlikte Araştırma/ İnceleme Talebi | Talep Etmiyorum |
| | | Acil Araştırma Raporu Talebi | - |
| Tarifname Dili | Türkçe | Genetik Kaynak | Hayır |
| Tarifname Sayfa Sayısı | 1 | Kaynağın / Bilginin Coğrafi Kökeni | - |
| İstem Sayısı | 2 | Kamu Desteği | Evet |
| Resim Sayfa Sayısı | 1 | Destek Sağlayan Kamu Kurumu | DİĞER |
| | | Proje Numarası | 24029 |
| Patent Sınıfı | G01N 33/497 | | |

BULUŞ BAŞLIĞI / ÖZETİ

| | |
|---|---|
| Buluş Başlığı | SmellControl ? Yapay Zeka Destekli Çok Kanallı Gaz ve Koku Algılama Sensörü |
| Buluş Özeti | SmellControl, makinelerin koku alma yeteneğini kazandıran çok kanallı nanohibrit gaz dedektörleri ve yapay zeka algoritmalarıyla desteklenen bir sensör sistemidir. 64 bağımsız algılama kanalı bulunan 3,7 gram ağırlığındaki nanomalzeme tabanlı sensörler, saniyede bir veri toplayarak her 1,8 saniyede 64 kanaldan gelen direnç değişimlerini analiz eder ve 5 saatlik ölçüm sürecinde yaklaşık 6000 veri noktası oluşturur. Azot, amonyak, nitrat, hidrojen sülfür, karbon monoksit, metan, fosfin, etanol, aseton, izopropanol, toluen ve binlerce farklı uçucu organik bileşiği (VOC) ppb seviyesinde algılayabilen bu sistem, geleneksel gaz dedektörlerinden 100 kat daha hassas olup çoklu gaz tespiti yapabilmektedir. Direnç değişimi prensibiyle çalışan sensörler, gaz molekülleri ile etkileşime girerek dijital sinyal desenleri oluşturur ve K-Nearest Neighbors (K-NN), Decision Tree, Gradient Boosting, Support Vector Machines (SVM), AdaBoost, Logistic Regression ve Derin Öğrenme tabanlı ağlarla %98 doğruluk oranıyla sınıflandırma yapar. IoT tabanlı entegrasyon sayesinde tarım makineleri, sanayi üretim sistemleri, akıllı şehir çözümleri ve sağlık hizmetleriyle senkronize çalışarak gerçek zamanlı veri sağlayabilir. Kullanım alanları arasında tarımda gübreleme optimizasyonu, endüstride gaz kaçaklarının tespiti, çevre güvenliğinde hava kalitesi izleme, sağlık alanında solunum yoluyla hastalık teşhisi, gıda endüstrisinde bozulma ve kalite kontrolü, kimyasal üretimde reaksiyon takibi, tekstil sanayisinde boya ve kimyasal bileşen izleme, biyomedikal uygulamalarda nefes analizi, parfüm ve aroma geliştirme süreçleri, atık yönetimi, iç mekan hava kalitesi izleme ve ergoterapi süreçlerinde duyusal değerlendirmeler yer almaktadır. Düşük enerji tüketimi (1μW), taşınabilirlik ve geniş gaz algılama spektrumu ile geleneksel sistemlere kıyasla daha verimli ve uygun maliyetli bir çözüm sunmaktadır. |

BAŞVURU SAHİPLERİ

| | | | |
|---|---|---|---|
| Ad Soyad/Unvan | YASİ* KARA** | | |
| TC Kimlik/Vergi No | 6548******* | Sahip Türü | Gerçek |
| Uyruk | TÜRK*** | Başvuru Hak Oranı | |
| Telefon | 5457****** | E-Posta | kara****************** |

BULUŞ SAHİPLERİ

| | | | |
|---|---|---|---|
| Ad Soyad/Unvan | YASİ* KARA** | | |
| TC Kimlik/Vergi No | 6548******* | Gizlilik Beyanı | Evet |
| Uyruk | TÜRK*** | Başvuru Hakkı Beyanı | Başvuru Sahibi |
| Telefon | 5457****** | E-Posta | kara****************** |

FATURA DÜZENLENECEK BAŞVURU SAHİBİ

| | |
|---|---|
| Ad Soyad/Unvan | YASİ* KARA** |
| Tc Kimlik/Vergi No | 6548******* |

DEKONT BİLGİLERİ

| | |
|---|---|
| Dekont Numarası | 25078BDIAFHVL1529-722940-3464148 |

TÜRK PATENT

PATENT APPLICATION

*Official Turkish Patent Institute document for Astrosit nanohybrid multi-electrode gas sensor (Patent No: 2025-GE-179248).*

**photo_5**


**TOGG CEO**

**MEHMET GÜRCAN KARAKAŞ**

*Astrosit founders presenting the prototype to TOGG CEO during industrial validation and partnership discussions.*

**photo_6**


*Astrosit team presenting the electric vehicle integration prototype at Teknofest — the world's largest aerospace and technology festival.*

**photo_7**



Elektrikli araçlar üzerinde yapılan çalışmalar /Yasin Karaca /Bilişim Vadisi / Teknofest

*Real-world documentation and analysis of EV thermal runaway and fire incidents emphasizing Astrosit's application relevance.*

**Astrosit Revenue Model Overview**

| Model Type | Target Audience | Revenue Source | Value Proposition | Scalability & Impact |
|---|---|---|---|---|
| B2C (Business to Consumer) | Individual EV owners, small workshop users | Device sales, mobile app subscriptions, AI diagnostics access | Real-time safety monitoring, personal gas detection, predictive alerts via mobile app | Builds user trust and brand awareness while ensuring continuous individual data flow for AI training |
| B2B (Business to Business) | Energy companies, EV manufacturers, smart infrastructure firms | Sensor integration, SaaS dashboard licenses, API-based analytics services | Continuous industrial monitoring, early risk detection, and ESG compliance support | Enables long-term institutional partnerships and sustainable recurring revenue through software-based scalability |
| Hybrid Data Model | Cross-sector R&D and government collaborations | Data analytics and industry partnerships | Contributes to digital gas mapping, national safety standards, and environmental data collection | Expands Astrosit's ecosystem into research, policy, and sustainability networks |

*Astrosit combines B2C and B2B revenue models to ensure sustainable growth. While B2C focuses on user safety through AI-driven devices and mobile monitoring, B2B targets industrial clients with real-time analytics and risk management solutions. Both models complement each other—consumer data enhances AI accuracy, and enterprise insights accelerate learning. The hybrid data model further supports public and research collaborations, positioning Astrosit as a leader in intelligent energy safety and sustainability.*

**First-Year Operational Budget Summary**

| Item | Description | Amount (₺) |
|---|---|---|
| Company Registration | Establishment and legal documentation | -30,000 |
| Financial Consultant | 4 months × 7,500₺ + 8 months × 10,000₺ | -100,000 |
| Equipment and Hardware | Lab, testing tools, and devices | -200,000 |
| Technopark Fees | Rent, workspace at Technopark (12 months) | -36,000 |
| Salaries (2 People) | Minimum wage + SGK × 12 months | -624,132 |
| Product Cost | 120 sensors × $200 (1$ = 41.32₺) | -991,680 |
| Software Licenses | One-time license payment | -30,000 |
| Total Expense | Total operational cost | -2,011,812 |
| Product Sales | 120 units × $330 (1$ = 41.32₺) | +1,635,264 |
| TUBITAK BIGG Investment | Non-refundable early-stage R&D grant | +900,000 |
| Development Fund Deduction | 3% of total revenue | -75,000 |
| Net Income | After deductions and grants | 2,460,264 |
| Net Balance | Net income – total expense | +448,452 |
| | | |

*Cost–revenue analysis for Astrosit's first operational year based on updated sensor production and sales figures.*

**Technical Design and Prototype**

| Component | Description |
|---|---|
| Sensor Chip (smell.iX16) | 16-channel carbon nanotube-based chip (23×12 mm, 0.1 g) operating from −20 °C to +70 °C with ultra-low power consumption (0.000001 W). |
| Detection Module | dentifies multiple gases and VOCs with high sensitivity and stability. |
| Support Chips | TLV2333, INA118, REF2030AIDDCR — used for signal amplification, data conversion, and precision measurement. |
| Circuit Board | Includes audio jack, power switch, connectors, steel wire, resistors, capacitors, and battery holder. |
| Power Source | 3.7 V, 45 mAh LIR2032 rechargeable battery. |
| Processor | Raspberry Pi-based microcontroller for real-time data collection and processing. |
| Outer Structure | Protective housing with modular ports, Type-C charging interface, and application integration. |
| Software | AWS cloud integration, mobile/web interface, and AI-supported data analytics platform. |

*Core hardware and software components of the Astrosit system, designed for precise gas detection, data processing, and AI-based safety monitoring in electric vehicle battery applications.*

**AuthorToEditor:** We would like to extend our sincere gratitude to the Scientific Committee for reviewing our submission. Astrosit represents a new generation of safety and sustainability technologies developed at the intersection of artificial intelligence, nanotechnology, and electric mobility. Our nanohybrid sensing system is specifically engineered to detect and classify hazardous gases within electric vehicle (EV) battery systems before critical thermal events occur. With over 98% detection accuracy and sub-2-second response times, the platform demonstrates exceptional reliability for early-warning diagnostics. Beyond its technical innovation, Astrosit contributes to global sustainability goals by enabling safer electrification and reducing the environmental and financial costs of EV-related incidents—estimated at more than $80 billion annually. Designed for real-time deployment in battery packs, charging stations, and smart grids, our solution enhances predictive maintenance, extends battery lifespan, and supports the clean-energy transition. We believe that Astrosit's scalable architecture and AI-driven analytics will play a vital role in shaping the next generation of electric-mobility safety standards across Europe, the United States, and Asia. We deeply appreciate the opportunity to present this research and look forward to future collaboration and knowledge exchange within the EV innovation ecosystem.

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