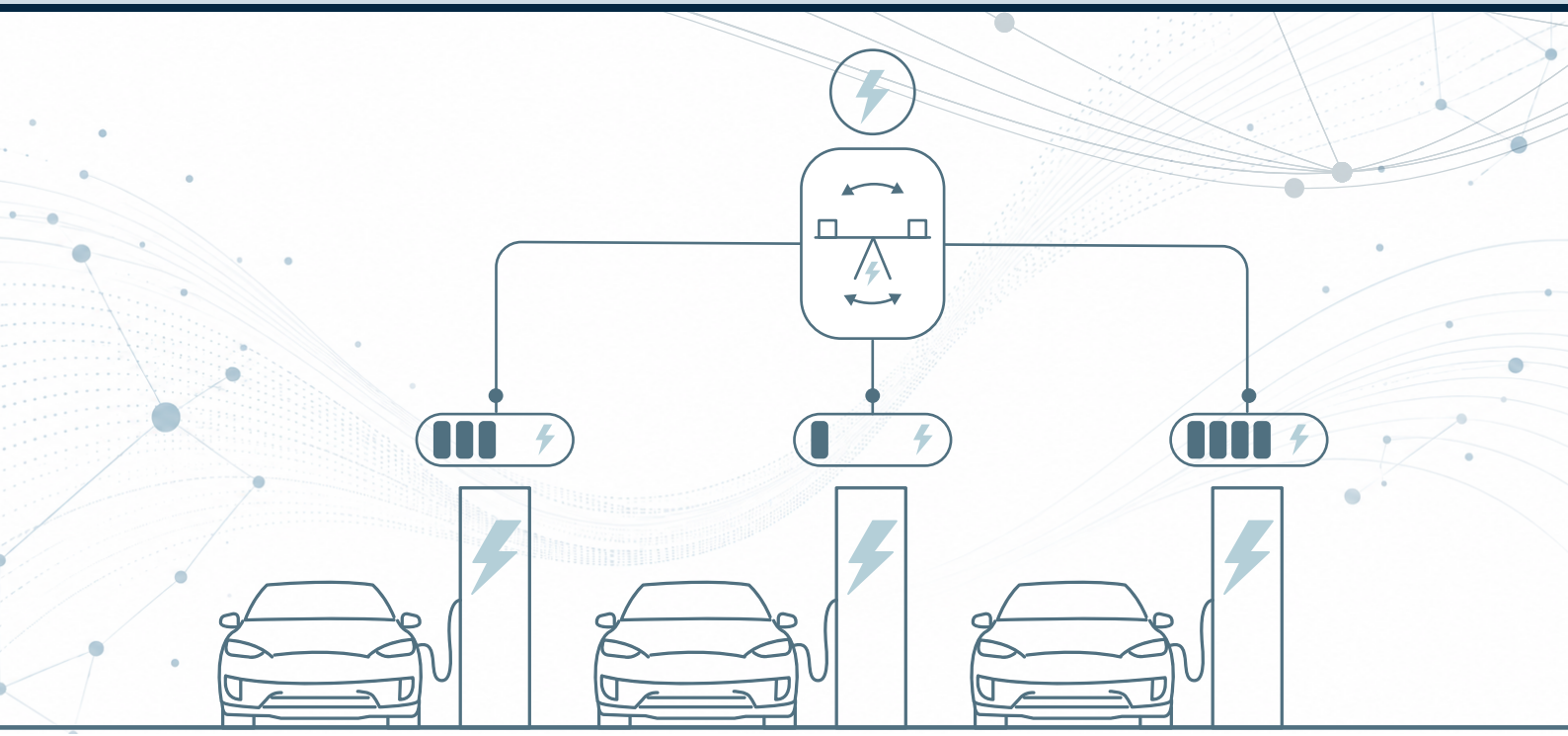
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White paper



Dynamic Load Balancing

The importance of energy control in the world of electrification and EV charging growth

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Dynamic Load Balancing for EV Charging Infrastructure: Maximizing Grid Efficiency and Charging Performance

INTRODUCTION

The rapid electrification of transport is reshaping energy demand patterns at sites that once had simple, predictable load profiles.
Car parks, logistics hubs, office buildings, retail centers, and public charging stations are now required to deliver significant amounts of electrical energy to multiple vehicles simultaneously — often within the constraints of a fixed grid connection that was never designed for this purpose.

This structural mismatch between available grid capacity and the growing demand for EV charging creates a fundamental challenge: how to serve as many vehicles as possible, as quickly as possible, without tripping protection systems, incurring demand charges, or requiring costly grid upgrades.

Dynamic Load Balancing (DLB) — also referred to as Smart Charging or Dynamic Load Management (DLM) — is the engineering response to this challenge. By continuously monitoring site energy consumption and automatically adjusting the power allocated to each charging point, DLB systems ensure that the total site load never exceeds the contracted limit, while still delivering the maximum possible charging power to connected vehicles.

As EV adoption accelerates and charging infrastructure scales from a handful of points to tens or hundreds per site, the importance of DLB grows accordingly. Understanding its technical requirements, regulatory context, and implementation options is essential for every actor in the EV charging value chain.



ABSTRACT

This white paper examines the technical and regulatory challenges associated with dynamic load balancing in EV charging infrastructures.

It provides practical guidance for site operators, system integrators, and OEMs on how to design, deploy, and manage scalable charging sites without exceeding available grid capacity.

The document also presents Carlo Gavazzi's UWP40DLB, a purpose-built local controller for dynamic load management, as a proven solution for both online and offline deployment scenarios.

WHY DYNAMIC LOAD BALANCING MATTERS

The Grid Capacity Problem

A typical commercial or industrial grid connection is sized for a specific maximum demand, expressed in kilowatts or amperes. This limit is defined by the utility and enforced by the site protection infrastructure. Exceeding it — even briefly — can trigger circuit breakers, result in supply interruptions, or generate significant penalty charges under demand-tariff schemes.

Each standard AC EV charger draws between 3,7 and 22 kW per phase. A site with ten chargers operating simultaneously at full power can therefore generate a peak demand of 37 to 220 kW — in addition to the existing building load from lighting, HVAC, and other equipment. Very few sites have grid connections that can accommodate this incremental demand without intervention.

The alternative — upgrading the grid connection — is technically straightforward but commercially prohibitive. Connection upgrades involve utility applications, civil works, new switchgear, and lead times that can stretch to months or years. For most operators, this is not a viable short-term solution.

Static vs. Dynamic Approaches

The simplest way to avoid grid overload is to apply a fixed limit to each charging point — for example, capping every charger at 50% of its rated power. This static approach is easy to configure but highly inefficient: it wastes available capacity when few vehicles are connected and may still fail to prevent overloads when all points are in use simultaneously.

Dynamic Load Balancing replaces fixed limits with a continuously adjusted allocation that reflects actual site conditions. When a vehicle completes charging or reduces its demand, the freed capacity is immediately redistributed to other active sessions. When the building load increases — for example, during morning start-up or peak production hours — the charging allocation is reduced proportionally.

The result is optimal use of every available ampere, at every moment.



MARKET AND REGULATORY DRIVERS

Explosive Growth in Charging Infrastructure

EV adoption is expected to continue growing rapidly through 2030 and beyond, driving significant investment in charging infrastructure.
Global charging points, both public and private, are expected to expand substantially over the next decade.

Growth is increasingly concentrated in multi-point charging environments such as fleet depots, logistics centers, commercial facilities and municipal charging hubs, where smart charging and Dynamic Load Balancing (DLB) can help mitigate grid constraints and optimize available power capacity.

Regulatory Requirements

Regulatory frameworks in multiple jurisdictions are now either mandating or strongly incentivizing smart charging capabilities as a condition for infrastructure approval or subsidy eligibility.
In the European Union, the revised Alternative Fuels Infrastructure Regulation (AFIR) requires that charging stations above certain power thresholds implement smart charging functionality. The EU's Energy Efficiency Directive and national building codes in multiple member states now require DLM-capable installations in new commercial buildings with parking facilities.

In the United Kingdom, the Electric Vehicles (Smart Charge Points) Regulations 2021 mandate smart charging capability for all domestic and workplace charging equipment. Similar requirements are advancing in North America under programs administered by the Department of Energy and various state-level utility commissions.

For operators and OEMs, these regulations mean that smart charging is no longer an optional premium feature — it is a prerequisite for market access in an increasing number of segments.



Protocol Standardization: The Role of OCPP

The Open Charge Point Protocol (OCPP) has emerged as the de facto communication standard between charging station hardware and back-office management systems (CSMS). The smart charging extensions of OCPP 1.6J and their further development in OCPP 2.0.1 and OCPP 2.1 define the messaging framework through which load limits are communicated to chargers.



OCPP-based smart charging enables interoperability between chargers from different manufacturers and backend systems from different vendors. For site operators, this is critical: it means that a local load balancing controller implementing OCPP smart charging profiles can manage any compliant charger, regardless of brand — protecting the operator's investment as hardware is upgraded or expanded over time.

TECHNICAL ARCHITECTURE OF A DLB SYSTEM

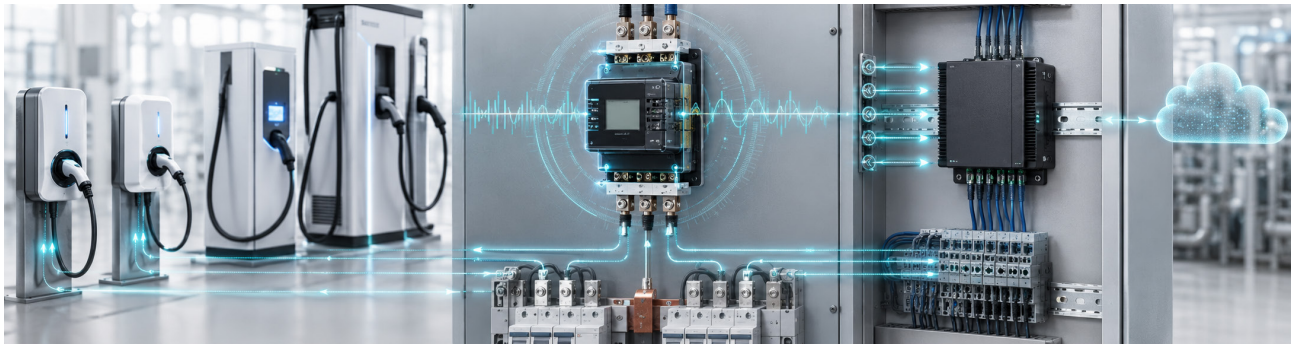
System Components

A complete dynamic load balancing solution for an EV charging site consists of three interconnected layers, each with specific roles and requirements.

The field layer comprises the EV charging stations themselves — the physical dispensers that vehicles connect to. These can be AC chargers (single or three phase, typically 3,7 to 22 kW per point) or DC fast chargers (22 to 350 kW or more). For DLB to function, the chargers must support smart charging via OCPP, which allows their output limits to be adjusted remotely in real time.

The site monitoring layer consists of a single energy meter installed at the site's main grid connection point. This meter provides the total power import of the installation in real time, allowing the controller to determine the available capacity without exceeding the site's contractual or physical limits. Since the DLB algorithm relies on timely measurements of the site's overall demand, accurate and low-latency metering at this single point is essential for reliable operation.

The control layer is the intelligence of the system. A local load balancing controller continuously combines the total site power measured by the main energy meter with the real-time charging power reported by each EV charger through OCPP. Based on this information, the controller dynamically calculates the available power margin and adjusts the power limits of individual charging stations via OCPP. Depending on the deployment model, the controller may also interface with a cloud-based CSMS for transaction authorization, billing, remote monitoring, and fleet management.



The DLB Algorithm

The core function of a DLB controller is to solve, continuously and in real time, a constrained optimization problem: how to distribute a limited total power budget across a variable number of active charging sessions, while respecting cable and circuit constraints and honoring any priority rules defined by the operator.

At each control cycle — typically every few seconds — the algorithm follows a sequence of steps. It reads the current total site consumption from the energy meter. It calculates the available headroom by subtracting this value from the configured site limit. It then distributes this headroom across all active charging sessions, applying any grouping constraints (such as separate limits for different cable runs) and priority rules (such as preferential allocation for fleet vehicles or vehicles with low state of charge).

The resulting individual limits are sent to each charger as OCPP SetChargingProfile commands. The charger is required to respect these limits and will reduce or increase its output accordingly. The cycle then repeats, allowing the system to track changes in both the building load and the number of active sessions.

Online and Offline Operation

In connected deployments, the local controller operates in tandem with a cloud-based CSMS.
The CSMS handles driver authentication, session authorization, billing, and fleet reporting. The local controller focuses on real-time load management, acting as a transparent proxy for OCPP messages between chargers and the CSMS while simultaneously applying load limits.

Connectivity failures — whether due to network outages or cloud maintenance windows — represent a critical risk for any system that relies entirely on cloud authorization. A robust DLB solution must therefore include a local fallback mode: the ability to continue managing load and authorizing sessions (via locally stored whitelist or RFID) even when the internet connection is unavailable. This ensures charging continuity for site users and protects operators from service disruptions.

KEY CONSIDERATIONS FOR SYSTEM INTEGRATORS AND OPERATORS

Site Assessment and Limit Configuration

Before deploying a DLB system, a careful site assessment is essential. The primary configuration parameter is the site power limit — the maximum total load that can be drawn at the grid connection point. This value must account not only for the contracted capacity, but also for the headroom required by other site loads and any demand tariff thresholds defined by the utility.

Cable capacity constraints must also be mapped: where multiple chargers share a common supply cable, the DLB controller must enforce sub-group limits that reflect the ampacity of that cable, independently of the site-level limit. Failure to model these constraints correctly can result in cable overheating even when the overall site limit is respected.

Scalability and Licensing

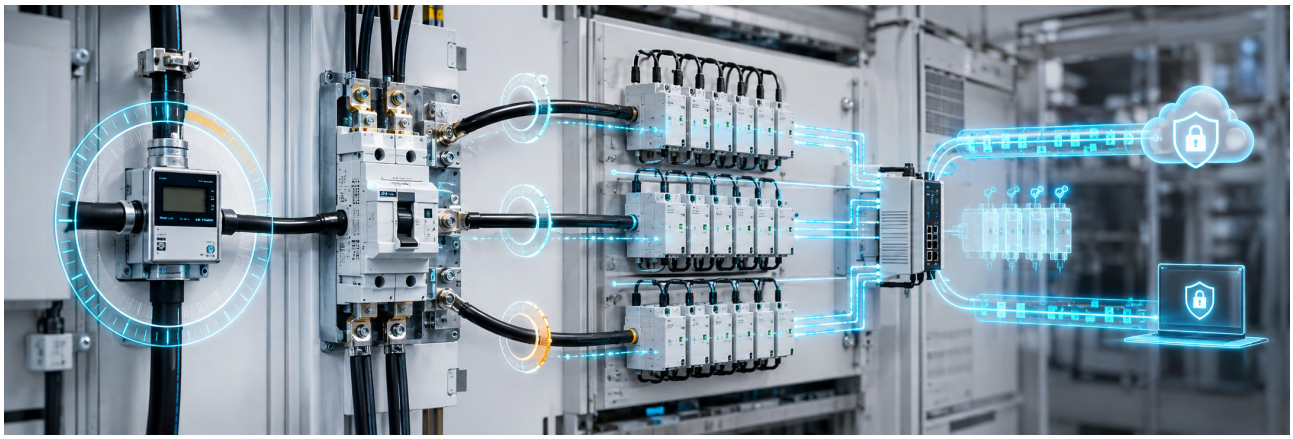
Site requirements evolve. A car park that begins with ten charging points may expand to fifty within three years as EV adoption among users grows. A DLB solution that requires hardware replacement to accommodate additional points imposes significant cost and disruption. Operators and integrators should prioritize solutions that offer software-based capacity scaling — where the controller hardware remains in place and additional plugs are enabled through license upgrades.

Metering Integration

The DLB algorithm relies on two complementary data sources. A single energy meter monitors the building load, allowing the controller to calculate the power available for EV charging as the difference between a predefined site power limit and the measured building consumption. At the same time, each charging station reports its real-time power through OCPP. By comparing the total charging power with the available capacity, the controller dynamically adjusts charger limits to ensure the site power threshold is never exceeded.

Authentication and Cybersecurity

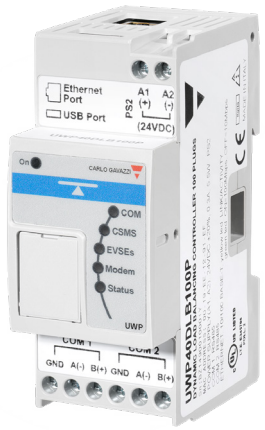
EV charging sites increasingly attract attention as a target for cyberattacks, both because of the financial transactions they handle and because of the potential for grid disruption that compromised chargers represent. DLB controllers that communicate with OCPP chargers and cloud backends over public networks must implement encrypted communication, strong authentication, and secure remote access. Controllers that support VPN-based cloud connectivity and HTTPS for local web interfaces provide a significantly stronger security posture than those relying on unencrypted protocols.



UWP40DLB

LOCAL CONTROLLER FOR DYNAMIC LOAD MANAGEMENT OF EV CHARGERS

- Manages up to 250 charging plugs (AC and/or DC) from a single unit
- Monitors OCPP messages relating to charging limits in real time
- Reads site energy consumption via energy meter (TCP/RS485, optional)
- Automatically adjusts per-charger limits to keep total load within site capacity
- Works with single and three phase systems
- Compatible with any OCPP 1.6 J Smart Charging-compliant charger or backend
- Supports charger grouping for separate cable run limits and priority channels
- Stores transactions with CSV and NEM12 export capability



MAIA CLOUD

SECURE REMOTE CONNECITIVITY PLATFORM

- Secure remote access to gateways and field devices through encrypted VPN tunnels.
- Cloud-based platform enabling safe connection to distributed installations from anywhere.
- No dedicated VPN servers are required thanks to the SaaS architecture and centralized web portal.
- Centralized user management with authentication and role-based access control.
- OTA (Over The Air) updating for an easy, quick and effective fleet management
- Easy integration with Carlo Gavazzi gateways and connected field devices.



CARLO GAVAZZI SOLUTIONS FOR DYNAMIC LOAD MANAGEMENT

Carlo Gavazzi has developed a comprehensive portfolio of hardware and software solutions for the management of energy systems in commercial and industrial applications. The company's expertise in energy monitoring, protocol gateways, and edge computing provides a strong foundation for EV charging infrastructure management.

UWP40DLB: The Purpose-Built Load Balancing Controller

The UWP40DLB is Carlo Gavazzi's dedicated local controller for dynamic load management of EV charging sites. Designed as a compact DIN-rail module, the UWP40DLB combines load balancing intelligence, OCPP communication, energy metering integration, and secure remote management in a single, field-proven device.

Online and Offline Deployment Modes

The UWP40DLB is designed to operate in two complementary scenarios, addressing the full range of site requirements.
In online mode, the controller acts as a local OCPP proxy between the charging stations and any OCPP-compatible CSMS. It passes authorization and billing messages transparently while simultaneously applying real-time load limits. Should the internet connection fail, the controller automatically maintains load management locally and can authorize sessions using a stored RFID whitelist, ensuring uninterrupted service for site users.

In offline mode, the UWP40DLB operates as a fully self-contained system, handling both load management and local authorization without any cloud dependency. Authentication is managed via RFID cards, making this mode ideal for fleet depots, private car parks, and sites where cloud connectivity is unavailable or undesirable.

Scalable Licensing Architecture

The UWP40DLB is available with embedded licenses for 10, 20, 50, 100, 200, or 250 charging plugs. When site requirements grow, capacity can be extended via software license upgrades — from 20 to 100 plugs, from 50 to 200 plugs, or up to the maximum of 250 plugs — without any hardware replacement. This architecture protects the operator's initial investment and significantly reduces the cost and complexity of site expansion.

MAIA Cloud Integration

The UWP40DLB integrates natively with MAIA Cloud, Carlo Gavazzi's secure remote management platform. Through MAIA Cloud, operators can configure the controller remotely, monitor charging site performance in real time, and receive software updates over the air — all through an encrypted VPN connection. This eliminates the need for on-site visits for installation or deployment and firmware maintenance, reducing total cost of ownership for multi-site deployments.

Connectivity and Integration

The UWP40DLB offers a comprehensive set of communication interfaces to support integration with diverse site infrastructure. An Ethernet port provides LAN connectivity and access to the embedded web server for local configuration and monitoring. Two RS485 ports enable connection to Modbus-based energy meters and other field devices. A USB port supports cellular modem integration for sites without fixed broadband. Chargers connect to the controller via OCPP WebSocket on port 8887 (WS) or 8886 (WSS, for wired internet connections).

The embedded web server, accessible via HTTPS, provides a powerful and intuitive interface for local configuration and real-time monitoring, accessible from any browser on the local network — or remotely via MAIA Cloud tunnelling.



CONCLUSIONS

The growth of EV adoption is placing unprecedented demands on site electrical infrastructure. Dynamic Load Balancing has moved from an optional enhancement to an operational necessity for any multi-point charging site — and an increasingly explicit regulatory requirement across major markets.

Effective DLB requires a combination of accurate site metering, real-time OCPP communication with charging stations, robust local control intelligence, and the ability to operate reliably through network failures. It must also be scalable, to grow with the site, and manageable, to minimize the operational burden on operators.

The UWP40DLB from Carlo Gavazzi addresses all of these requirements in a compact, certified, and field-proven package. Its support for up to 250 charging points, flexible online and offline operation, scalable licensing, and integration with MAIA Cloud make it the right foundation for EV charging infrastructure at any scale — from a small workplace car park to a large public charging hub. UWP40DLB is also compatible with any charger that supports smart charging through OCPP Charging Profiles (OCPP 1.6J or 2.x.x).
As the EV charging market continues to mature, the ability to maximize the use of available grid capacity will become a key competitive differentiator for site operators and a core competence for system integrators. Carlo Gavazzi's experience in energy monitoring, edge control, and industrial communication protocols positions the company as a reliable partner for this transition.

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