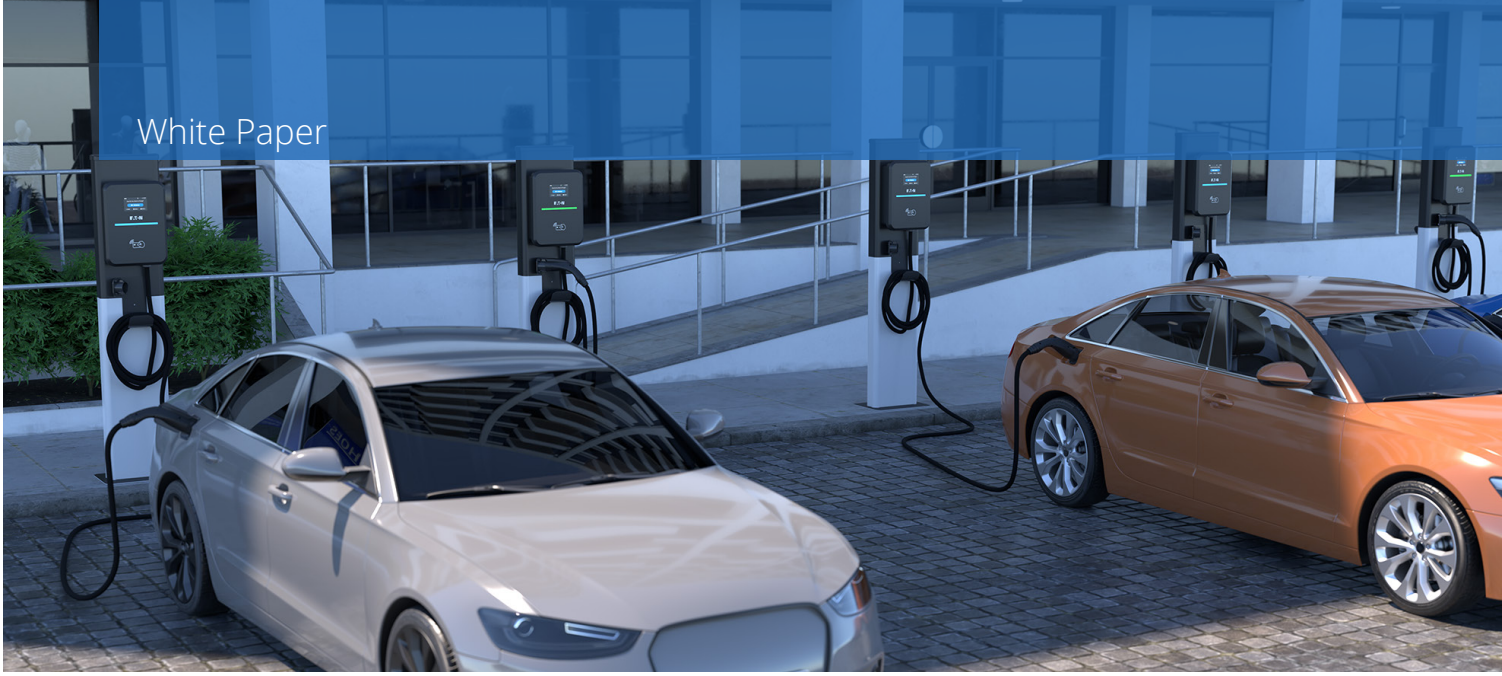
White Paper



EV charging load management: Accelerating electrification and making the most of available energy

Mitch Simmons, P.E.
Technical Marketing Lead
Connected Solutions
Eaton

Brad Juhasz
Offer Manager – Software
Connected Solutions
Eaton

Overview

Electrifying transportation hinges on more charging infrastructure. Load management stretches electric systems—enabling more chargers and a better experience for drivers. And it's especially important as the infrastructure updates and upgrades required to add electrical capacity take time.

This guide provides an overview on electric vehicle (EV) load management architectures, detailing both passive and dynamic approaches for multi-family, commercial and fleet applications. It also explains how a fully integrated approach—including EV load management software, charging hardware and electrical infrastructure—delivers on reliability and an improved driver experience, optimizing charging speed and infrastructure.

Powering Business Worldwide

Market trends: the future of transportation is electric

By 2030, the U.S. is aiming for electric vehicles (EVs) to make up half of all vehicle sales and build a national network of more than 500,000 installed EV chargers. And the National Electric Vehicle Infrastructure Formula Program, established by the Infrastructure Investment and Jobs Act (IIJA) of 2021, will distribute up to USD $5 billion in funds from 2022-2026 to support the development of an EV charging network, with a target of 500,000 chargers. Already, the U.S. installed 6,300 fast chargers in 2022 (reaching a total of 28,000 fast chargers).

A recent S&P Global Market Intelligence eMobility report commissioned by Eaton examined automotive eMobility infrastructure and the interdependencies from EV sales, consumer perspectives and regulatory milestones. In part, the report found:

- There is strong growth in electric vehicle supply equipment (EVSE) and the scales are tipped strongly toward Level 2 AC installations (due to cost and compatibility).
- EV drivers will fuel where they park (not driving to fuel), and most consumers are unfamiliar with this fact.

Further, when it comes to EV adoption, survey respondents ranked "charging availability" as the top influencer, followed by "charging speed" and "pricing and incentives"—which were tied for second place.

Charging infrastructure is an important and well-recognized barrier to purchasing an EV or hybrid vehicle. Most survey respondents believe that existing charging infrastructure was insufficient for their charging needs (even though most respondents were also those who had never owned an EV or hybrid vehicle in the past).

EV drivers will charge when and where they can. Mainly, wherever they park. This a different mindset than driving to refueling locations, which is what most people are accustomed to today.

This means most EV charging will occur at home. Yet, public charging stations will be essential for convenience, accessibility and confidence. Access to public and workplace charging is important, especially for people who live in multi-unit dwellings, where charger availability maybe limited.

Managing the inevitable need for more electricity

Electrifying transportation will create surging demand for electricity, with electrification efforts in transportation and building systems expected to increase electrical demand 50% by 2050.

According to McKinsey, most U.S. electric grids can provide sufficient electricity to meet demand from EV charging. But few can easily "deliver large amounts of electricity to many EVs at highest rates at the same time."

EV fleets can have implications for peak power demand, transmission and distribution capacity. Both for fleet depots and building energy management systems, accommodating the EV charging may require infrastructure upgrades and/or added capacity. It can take a significant amount of time for utilities to upgrade infrastructure to deliver these new levels of power. EV load management can help fill the gap—maximizing the number of chargers available and optimizing power, as much as possible, given the constraints of the available power supply.

EV charging is critical infrastructure for fleets. While EV load management may work for light-duty fleets over the long run, it is likely not the long-term approach for applications where you have many vehicles that need a full charge every day. That said, it can help bridge the gap, optimizing existing electrical capacity if there is a waiting period to update or upgrade your electrical service.

When it comes to drivers' experiences, using load management software will enable more drivers to charge at the same time. However, it may take longer than anticipated to get a full charge (depending on available capacity and the number of vehicles being charged).

EV load management enables an automated and creative means to make the most of available energy and time-of-use utility rates. These systems can manage and adjust the energy available for charging—enabling the fastest possible charge across networked chargers without overloading networks. Simply put, EV load management software enables you to install more chargers than your infrastructure can otherwise support, maximizing the number of chargers and simplifying deployment and management of networked EV charging stations.

Load management is vital

As EV adoption surges, demand for charging stations is increasing and load management becomes more important. What does it mean and how does it impact EV charging deployments?

Broadly speaking, load management involves controlling loads or power demand to limit the total power applied to an electrical system. EV load management involves controlling the EV chargers, which is the focus of this guide.

EV load management enables you to install more chargers and electrify more areas of your parking area without overloading the electrical systems.

When it comes to limiting power, this can be accomplished at the circuit, panel, building or the utility transformer level. The complexity of load management increases as the system moves up the electrical infrastructure chain; controlling a single EV charging station at the circuit level is less complex than controlling a series of EV chargers at the utility-transformer level.

EV load management can be accomplished in two ways to limit power demand: passive/static and dynamic load management. Passive load management does not monitor anything external to the EV charging station. Dynamic load management monitors external factors (beyond the EV chargers) to determine how much charging power is available to be dispensed.

What's the difference between EV load management, EV load balancing and EV load scheduling?

EV load management involves controlling the amount of power available for chargers. Advanced load management software can balance loads by distributing available power across charging stations, optimizing charging based on available capacity and vehicles' rate of charge. Whereas EV load scheduling involves setting charging times during which charging can occur. EV load scheduling takes advantage of off-peak rates (reducing your electric bill). Load scheduling should be possible with basic EV load management functionality and EV load balancing can occur simultaneously with load scheduling.

How does passive EV load management work?

Passive load management works via adjustable setpoints to the charging station or by splitting power for dual port charging stations. There are two typical ways to implement adjustable setpoints: physical switches or password protected digital setpoints that limit the charging station to a fixed amount of power. To split power for dual port charging stations, passive load management evenly shares power to the two vehicles.

In either case, passive or static load management is a low-cost approach that's typically built into the EVSE and does not require a network connection. While it could provide the needed functionality in a single-family home, passive load management has the potential to create a poor customer experience in workplace, commercial and retail settings. This is because customers may expect to charge their vehicle at a faster rate, and the charge session may not meet their needs.

How does dynamic EV load management work?

Dynamic load management is typically accomplished by creating a digital twin of the electrical system with the EV supply equipment and other loads, and automatically managing and adjusting the energy available for charging. This is all to enable the fastest possible charge across networked chargers without overloading the electrical infrastructure.

Dynamic load management is primarily used in multi-family, workplace, commercial and fleet applications. Importantly, it requires close coordination with all the stakeholders involved in designing, planning, installing and managing EV charging at a facility or campus.

There are three typical methods to accomplish dynamic load management, and depending on the system, they can be mixed and matched to optimize charging and improve user experience:

1. **EV load leveling**
2. **Adaptive EV load management**
3. **Site responsive EV load management**

EV load leveling

Digital twin throttling of individual charging stations evenly splits energy among chargers based on a maximum load setpoint. The maximum setpoint is set within the digital twin, which monitors the connected EV charging stations and compares the total load to the setpoint. As every new charger is plugged in, the load management system throttles all the chargers to not exceed the setpoint. As long as the total rating of the chargers does not exceed the electrical capacity, charging stations can operate at full power. As soon as the total rating of the chargers exceeds the rating of the panel, one of two scenarios occur; charging is either divided evenly to not exceed the rating of the panel, or the last EV plugged in is not allowed to charge until another EV completes its session.

Scenario:

- **Four 32A chargers sharing a breaker with a 100A rating**
- **80A limit used for power management (80% maximum continuous load)**

1 Four charge stations available and online.

Charger A	Charger B	Charger C	Charger D
—	—	—	—

2 Two drivers plug in to Chargers A and B; each get full power.

Charger A	Charger B	Charger C	Charger D
32A	32A	—	—

3 A 3rd driver plugs into Charger C and all throttle to share power.

Charger A	Charger B	Charger C	Charger D
26A	26A	26A	—

4 A 4th driver plugs into Charger D and all throttle to share power.

Charger A	Charger B	Charger C	Charger D
20A	20A	20A	20A

Adaptive EV load management

A more advanced approach to dynamic load management makes use of the fact that not all plug-in vehicles will charge at the same rate at the same time. This involves digital twin throttling using a maximum load setpoint as the basis for throttling, plus it incorporates monitoring active charge sessions to determine the charge rate of the other connected stations.

This approach takes advantage of the reality that plug-in hybrid vehicles (PHEV) typically have smaller chargers on board, compared to a battery EV (BEV). Further, as the battery pack reaches more than 90% state of charge, the rate of charging typically begins to decrease. When these factors are integrated into an EV load management system, it can throttle individual chargers based on both the maximum total load and the individual vehicle and redistribute unused power to stations and vehicles that can take advantage of its availability.

Scenario:

- **Four 32A chargers sharing a breaker with a 100A rating**
- **80A limit used for power management (80% maximum continuous load)**

1 Four drivers plug in and power is equallity distributed.

Charger A	Charger B	Charger C	Charger D
20A	20A	20A	20A

2a Charger A completes and power is redistributed.

Charger A	Charger B	Charger C	Charger D
—	26A	26A	26A

2b Vehicle at A is charging at a lower rate. Charger A is maxed at lower output and remaining power is shared across other stations.

Charger A	Charger B	Charger C	Charger D
10A	23A	23A	23A

Site responsive EV load management

With this approach, the EV load management system actively monitors the facility load and adjusts the EV charging setpoints in real time. In other words, this load management architecture looks at the source and total facility or campus load and uses the difference in demand load and maximum capacity to set the EV charging limits.

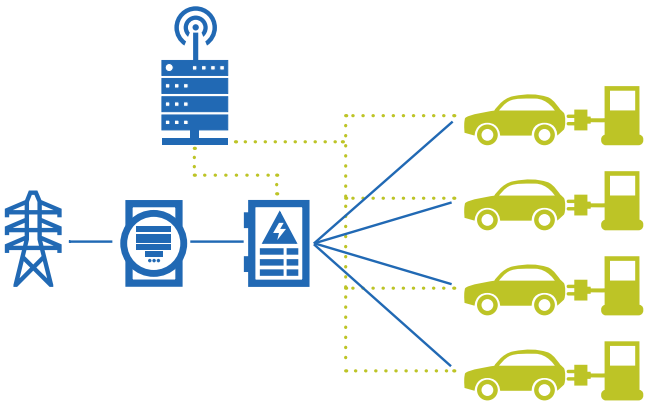
Scenario:

- Four 40A EV charger
- 160A available power
- Local EV load management controller, monitoring available power

So, if facility has a main incoming service rating of 2000A and the facility load is 1200A, then the system will calculate that 800A are available for EV charging. When the facility load increases to 1500A, then the EV load management system will calculate that 500A are now available, adjusting the charging setpoint not to exceed 500A.

This architecture requires accessible and compatible meters and EV load manager controller. It may also require an internet connection to support additional features like access control and charge session payments.

EV load management controller

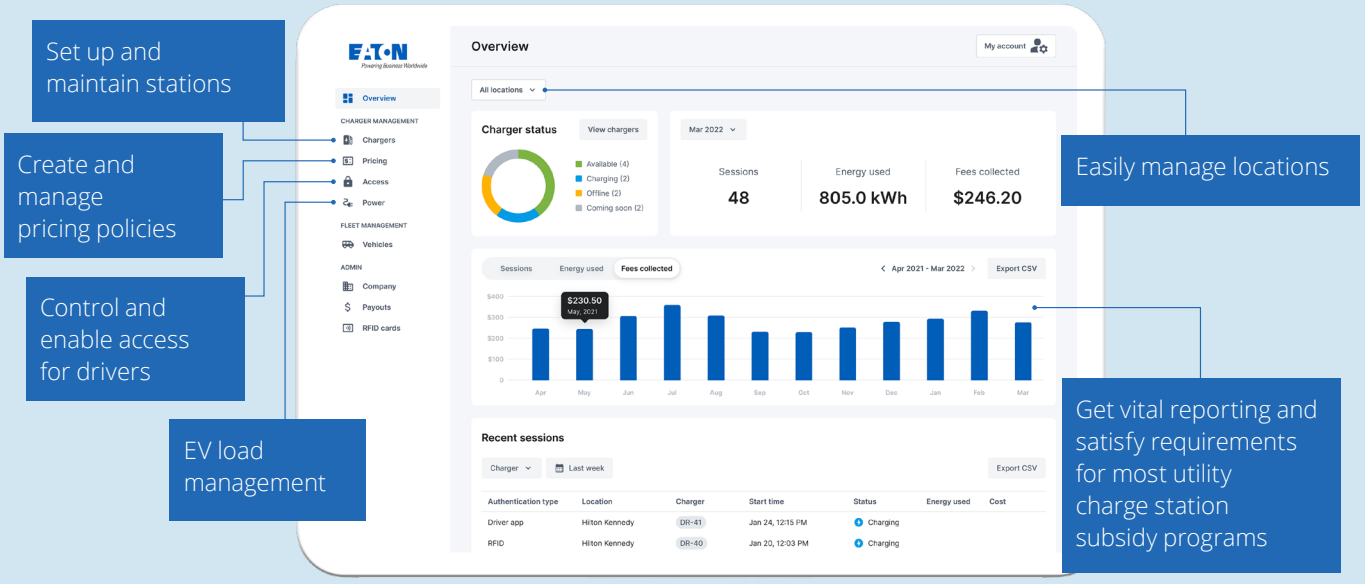


Controller actively monitors available power

Load management methodology comparison

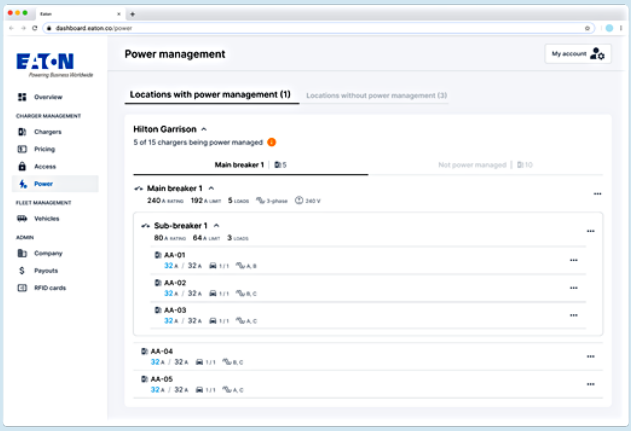
Technology	Type	Advantages	Disadvantages	Where used
Fixed adjustable setpoints in EVSE	Passive/ static	Low cost (built into EVSE) Does not require a network connection	Unused capacity Limited capability	Single family residential Retrofit of exisiting legacy charging stations
Power split for dual port charging stations	Passive/ static	Low cost (built into EVSE) Does not require a network connection	Potential poor customer experience Certain models can be costly	Workplace Commercial Retail
EV load leveling	Dynamic	Allows for reduced infrastructure cost Can be accomplished with current cloud based systems	Requires close coordination with design engineer, installing contractor, customer, and EV load manager Loss of connectivity can limit charge station usage until connectivity is restored Cannot automatically adjust for changing site conditions (other loads added to same panel, etc.)	Multifamily Workplace Commercial Fleet
Adaptive EV load management	Dynamic	Allows for reduced infrastructure cost Can be accomplished with current cloud based systems Potential better customer experience	Requires close coordination with design engineer, installing contractor, customer, and EV load manager Loss of connectivity can limit charge station usage until connectivity is restored Cannot automatically adjust for changing site conditions (other loads added to same panel, etc.)	Multifamily Workplace Commercial Fleet
Site responsive EV load management	Dynamic	Provides close to real time active adjustments of EV charging Makes good use of available capacity for existing systems	Complexity Requires accessible metering at the service Requires on premise load controller May still require cloud connectivity for other feature (access control, payments)	Large EV charging deployments Existing buildings with excess capacity

Active EV charge station management requires external controls



Charging Network Manager software is vital

Eaton's Charging Network Manager (CNM) software delivers breakout capabilities—making it easy to deploy, manage and monetize EV charging. It enables smart load management to stretch the capabilities of electrical systems, providing both static and dynamic load management. Plus, Charging Network Manager supports a robust EV charging ecosystem that can be managed with one intuitive dashboard.



The Eaton CNM utilizes the adaptive EV load management algorithim to provide dynamic load management capabilities for EV charger deployments. This can enable a faster charger and better experience for drivers. Plus, it enables you to install more chargers without overloading the system.

Beyond load management, the Charging Network Manager provides essential capabilities to simplify deployment and management of EV charging stations:

- **Monitoring and management of EV charge stations**
- **Reporting on uptime to meet federal funding requirements**
- **Overseeing charging locations and stations**
- **Tracking costs**
- **Monetizing charging sessions**

Building and fleet managers have access to all their EV charging network data in one place. And that data can be integrated into fleet management and other systems through an API. Beyond EV charging hardware and software, Eaton provides all the power management solutions to support charging infrastructure. That includes the meters and other smart hardware that enable advanced site responsive load management schemas.

Making the electric work

As EV adoption surges, the need for more electricity is certain. Infrastructure needs to work smarter and harder to enable and accelerate electrification, especially as increasing electrical capacity takes time. In this environment, intelligent electrical systems that are scalable and modular—and can stretch the capabilities of existing infrastructure—are a must.

EV load management helps optimize the potential of existing energy systems. It enables you to maximize the number of chargers and supports the fastest possible charge times across networked chargers without overloading infrastructure. The big question then, is what kind of load management do you need?

Nearly every EV charging deployment is unique and will invariably change over time. Creative and proven solutions enabling flexible and modular energy systems are essential for EV charging deployments. At Eaton, we have the hardware and software you need to optimize your infrastructure. So, you can meet your EV charging objectives today while creating a flexible foundation for whatever comes next.

About Eaton

Eaton is an intelligent power management company with 2022 revenues of $20.8B that is dedicated to improving the quality of life and protecting the environment for people everywhere. By capitalizing on the global growth trends of electrification and digitalization, we're accelerating the planet's transition to renewable energy and helping to solve the world's most urgent power management challenges. 2023 marks Eaton's 100th anniversary of being listed on the New York Stock Exchange. For more information, visit Eaton.com.

For more information, visit
Eaton.com/evchargers

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

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