Simplifying the road to total electric

How Solution Architectures Improve
Deployment for EV Fleet Depot Charging

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Introduction

The rise of fleet Electric Vehicles (EVs)
Cities across the world are experiencing a new wave of accelerated growth and associated infrastructure development. One key area of focus, to accommodate this growth while maintaining progression towards a greener urban future, is the electrification of vehicles.

It is estimated that the transportation of people and goods is responsible for over a quarter of total global emissions. With governments the world over enforcing ever more stringent emission targets, owners and managers of bus and truck fleets are looking towards electrification to reduce their environmental impact.

Between 2020 and 2030, the number of electric fleet vehicles is projected to rise from 13 million, to 127 million[1], as the industry wakes up to the cost and asset benefits of EVs compared to internal combustion engines (ICEs).

More than just lower emissions
The lower carbon emissions of electric buses and trucks are well documented, and for many countries, environmental preservation is the key driver for change.

That said, there are many operational benefits to making the switch to total electric. The working life of an EV is at least 2.5 times longer than ICEs and charging (fuel) costs are lowered by a factor of five. Maintenance costs are reduced by up to 25 percent and low noise levels make them ideal for large urban fleets where noise pollution is a concern.

The road to total electric
Fleet operators and transportation authorities now face the challenge of electrifying their fleets, in many cases against timeframes dictated by upcoming regulatory changes.

Make no mistake, completing the switch to electric is a major operational shift. While much media attention is given to the EVs themselves, less is said about the electrical and mechanical infrastructure required to provide optimized power distribution, energy management and in-depot charging capabilities.

Without the right advice and consultative support, these factors can significantly delay progress - but the road to electric can be simplified.

One of the biggest barriers to EV fleet deployment is EV fleet depot charging. This guide explores how solution architectures can overcome this hurdle, using case studies to showcase industry success stories, and ending with a roadmap for private fleet owners and transportation authorities who are ready to begin their journey to total electric.

Typical applications

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01 Bus depot
Medium voltage grid connection, typically overnight charging at depot

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02 eBus en-route charging
Medium voltage grid connection, typically 3 to 6 minutes at depot or in route

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03 Industrial fleet
Medium voltage or low voltage grid connection, typically overnight charging at depot

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04 Commercial fleet
Medium voltage or low voltage grid connection, typically overnight charging at depot

Planning for the deployment of EV fleet depot charging

Key considerations

A successful transition from a fleet of traditional diesel or petrol vehicles to one which is completely electric depends on the correct deployment of depot charging infrastructure.

This infrastructure is the backbone of any electric fleet and must meet the associated power requirements of the vehicles to be charged. With this in mind, there are three sets of considerations when planning the deployment of EV fleet depot charging:

1. **Infrastructure considerations:**
   Site considerations, initial cost outlay and utility connections

2. **Electrical considerations:**
   Grid limitations, charging efficiencies, mitigation of peak loads and controlling the power system

3. **Mechanical considerations:**
   Cable management, safety requirements and modular systems

1. Infrastructure considerations

Existing site conditions
The first stage of consideration is to examine the existing site conditions, especially for customers wishing to convert an existing site from ICE to EV. The electrical infrastructure needed to charge the vehicles will require additional space and provisions. While this can be taken into early consideration when planning and building a new depot from the ground up, lack of space can be an issue when retrospectively adding infrastructure to existing sites.

The cost of initial infrastructure
It is no secret that the initial infrastructure investment can be significant.

Costs depend on a variety of factors, including the existing site specifics and whether you are building on a brownfield or greenfield location. There will be several times as much electricity required on-site compared to an ICE depot and this must be planned accordingly in conjunction with the utility provider. There is of course, the option of combining power from the grid, with renewable power generated on-site. For this, a microgrid approach will be required.

Utility connections
Electric utility connections can present many challenges depending on the amount of power available, the quality of the power, the addition of renewables and on-site generation, plus back-up power and cost parameters like peak demand and time-of-use charges.

It is essential to balance the system and ensure that the required load is matched by available power, be it from a local utility provider, local storage or local production.

Vehicle range and additional charging opportunities
When deciding which depot infrastructure is most feasible, it is important to consider vehicle range and the availability of en-route charging, also known as opportunity charging.

In other words, how far will the vehicles be able to travel before recharging once they have been charged at the main depot overnight? How many additional en-route charging facilities will be required?

En-route, or opportunity charging infrastructure is typically high power with a medium voltage input from the grid for multiple chargers (inputs at each charger are usually 400 or 480 VAC but can vary by local requirements). This offers maximum charging in a short space of time such as when a bus is loading or unloading.

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05 Pantograph-down en-route charger

The importance of consultative expertise
During this early stage of consideration, electrification expertise and consultation is highly recommended and would typically follow this path:
- A full site assessment of existing facilities
- Define a general layout for the placement of a new infrastructure
- A power study analysis performed in conjunction with the utility provider
- Simulations produced to establish the point of connection and whether energy storage is required – if so, determine the most balanced Battery Energy Storage System (BESS) for the site
- Possible use of Artificial Intelligence (AI) to regulate BESS charging and discharging schedules based on the site states and scenarios to maximize asset lifespan and minimize utility demand charges

2. Electrical considerations

The initial deployment of EV fleet charging infrastructure, and the ongoing adaptation of this equipment to facilitate fleet growth are important considerations. The grid has limitations and adding more vehicles will require a thorough understanding of efficient charging processes, mitigation of peak loads and overall control of the site's power system.

Safety
It is likely that depot charging infrastructure will be located close to public access areas. For safety, it is crucial that the higher voltage electrical switchgear and components be located within the main building or within a tested and validated electrical enclosure or eHouse.

Upgrading the electricity supply
In some cases, the electrical grid will need to supply well over 10x the power required for a combustion engine depot. This increased power often requires the site's electricity supply to be upgraded to a medium voltage service of 1,000 to 42,000 volts. This may not be a concern right away, but considering the potential growth of your fleet is essential in case it becomes relevant in the future.

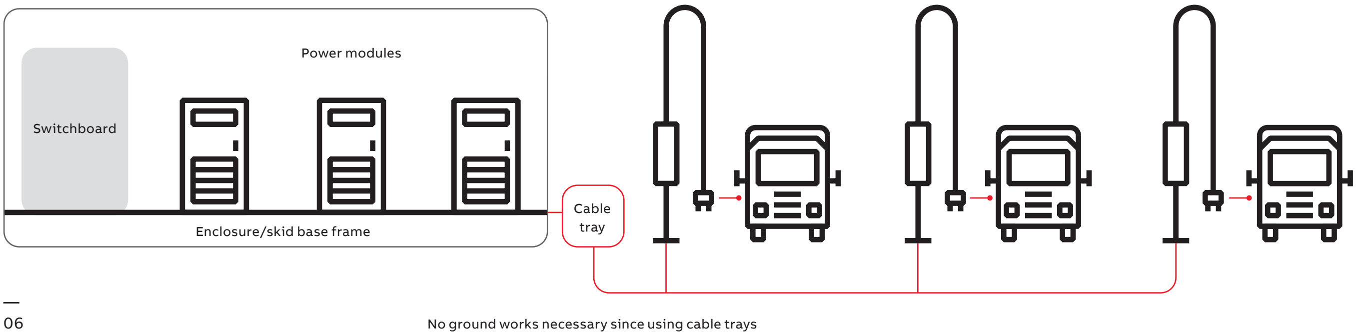
Energy storage
Energy storage solutions may be essential for certain charging depot applications for the following reasons:
- Locations with constrained grid power
- Low-voltage connections
- Poor quality power
- The use of on-site power generation

In addition to these factors, the day-to-day energy and power demands, the number of vehicles and the time of day that the vehicles are charged can also drive the need for on-site energy storage.

For smaller depots, the use of battery storage can prevent the need for an upgrade to a medium voltage service by 'topping up' the power from a standard low voltage supply when the vehicles are in use and not being charged. In other words, the BESS will charge during the day and discharge overnight when vehicles are charging.

Likewise, for bus depots, one option may be to add solar generation with load optimization in conjunction with the BESS. This architecture will help to minimize the utility infrastructure requirements and provide a good first step towards fleet electrification.

A well-designed architecture will link the BESS to the photovoltaic generation and utility depot. These systems can be configured with relocatable energy storage to allow site locations to be evaluated without premature permanent infrastructure costs.



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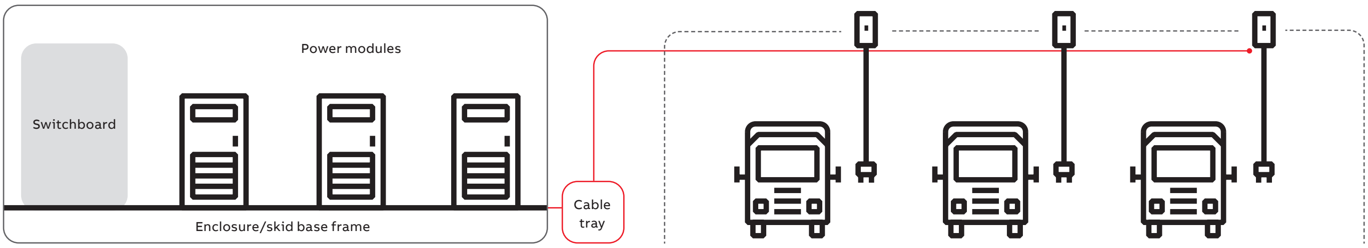

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06 Fast deployable power option utilizing containerized or skidded electrical distribution equipment with pre-configured cable management to the charger dispensers

07 Fast deployable power option utilizing containerized or skidded electrical distribution equipment with pre-configured overhead cable management to the charger dispensers

08 Fleet electrification installation

Digital management system
A well-deployed digital management system will coordinate the electrical grid, infrastructure, chargers and vehicles so that they all work efficiently together.

Examples are “simple” load management systems that ensure charging on a site does not exceed the available grid limit. More advanced systems will optimize the charging behavior taking into account the fleet schedule and limitations in the available grid connection, peak tariffs and fluctuating energy prices.

Digital management systems will not only monitor the charger conditions and the state of the infrastructure but will also execute control routines and alerts when required. This type of management system can sequentially charge fleet vehicles to reduce the pressure on the grid. Some of the more intelligent digital management systems can even use AI to optimize the charging routine of a system based on the site states and scenario.

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3. Mechanical considerations

Cable management
The primary mechanical consideration for any high-power vehicle charging depot is providing a path between the charger (power source) and the vehicle inlet.

This path may consist of overhead or underground cable management. A proper site design architecture early in the process will result in a better outcome. Some situations might work best for a fixed length cable to the side of the vehicle while others work best with a retractable overhead mechanism. Parking space and vehicle pathway layout is often the major factor in designing the cable management.

Automatic charging systems
As an alternative, automatic charging solutions, such as a pantograph connection system will raise the connection interface from the top of a vehicle or lower it onto a vehicle automatically to connect the vehicle with the charger.

With a mechanical system designed to connect high-power chargers, this solution can handle a large cable payload and can also ensure sufficient contact force at the interface before charging.

Since much of the mechanical concerns have been addressed in the pantograph design, this type of connection device may provide a solution to future mechanical challenges associated with higher power charging.

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09 En-route charging

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Mechanical safety requirements
In many charging depot applications, a medium voltage grid tie-in is necessary to meet the charging power requirements. Such high-power distribution equipment is regulated by government and local standards to ensure safe operation, especially in public areas. Factory assembled, pre-wired, and pre-tested modules are a good solution to reduce risk and ensure smooth deployment.

To assure safety and compatibility across the system, all electrical components should be compliant with IEC and / or IEEE (UL) standards.

Scalable, stackable, and modular solutions
Depot conversion projects often take place around an operational fleet. As a result, the start-up schedule is usually constrained and there are often concerns around how to fit the fleet and depot infrastructure into an urban site where the footprint is minimal.

Regardless of the specifics, fleet owners could consider solution architectures that are prefabricated and delivered in transportable modules to reduce install time and ensure reliability.

Modular ISO style enclosures are easily installed, resolving the construction challenges that are common for medium and low voltage power distribution equipment. Additionally, this enclosure solution saves depot operators time and space by making the modules semi-transportable, stackable, and scalable to accommodate future fleet growth.

What are solution architectures and how do they improve deployment for EV fleet depot charging?

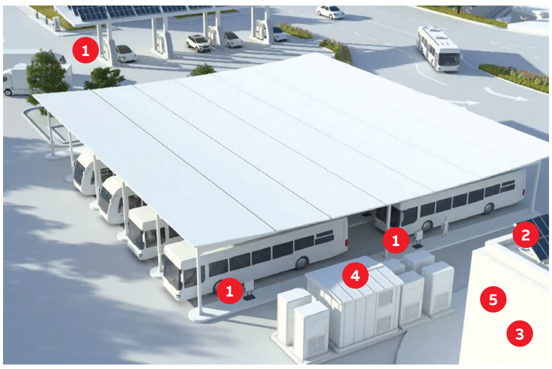
A solution architecture approach to deployment of depot charging infrastructures provides value as a pre-engineered optimized solution. It reduces site work and ensures smooth startup, irrelevant of fleet size or the complexity of the site to be developed.

Solution architectures can combine a range of optimized network components, such as the ones described in this whitepaper. They deliver faster drawings, manufacturing cycles and streamlined start-up and commissioning processes, to encourage rapid deployment of charging infrastructure.

Scalable and repeatable designs
Solution architectures can be standardized for use across sites. This helps operations scale the electrification of their fleet with high-quality, repeatable plans that are reliable.

Rolling out the same or similar design also makes ongoing training easier and more affordable and delivers predictable project schedules.

Module deployment for a gradual fleet electrification
Implementing solution architectures can often be achieved on a modular and scalable basis. This allows for simplified upgrades or additions as the fleet operation grows and increases its power and electrification infrastructure needs.



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10 Depot charging installation showing
1) charging dispenser
2) optional renewable generation
3) electrical equipment eHouse
4) electrical distribution equipment
5) control system station

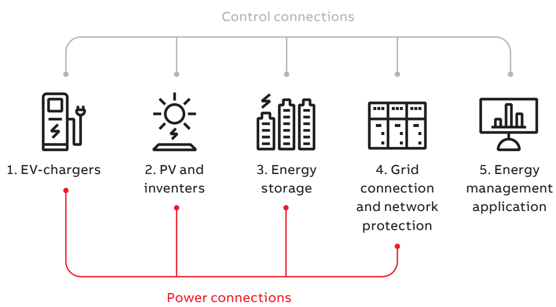
Combining the right elements for success
Solution architects will take time to understand the needs of each individual facility, before drawing on their expansive knowledge of all infrastructure components to design a full optimized solution. When it comes to retrofitting existing sites, charging infrastructure is not an ‘off the shelf’ service, and working with a solution architect can ensure each vital element is exactly fit for purpose.

The importance of consultative expertise
Employing an expert, such as an ABB Solutions Architect, to navigate the deployment of your depot charging infrastructure will ensure the most energy efficient and cost-effective road to total electric.

ABB Solution Architects are leading with technology by translating a traditionally customized project into a pre-engineered productized solution for reduced risk, improved lead times, and optimized construction to ensure ABB is well-placed to support customers with projects in nearly every country across multiple segments and applications.

Solutions architectures will provide a blueprint for future scalability and the electrification of further sites within any organization, ensuring the same level of quality as your fleet requirements change.

Customer requirement: e-Vehicle depot electrification and energy optimization



Exploring solution architectures
Popular schemes explained

When it comes to electrifying ICE fleets, solutions architects have a wealth of expertise to allow them to tailor technologies and infrastructures to each specific site, the requirements of the location, the available power, and the needs of that particular fleet.

Four popular schemes are:
1. Depot architecture with grid connection
2. Depot architectures with on-site power generation
3. Depot architectures with energy storage solutions
4. Digitally integrated depot architectures

1. Depot architecture with grid connection

At present, this is the most popular solution architecture. Architectures with a direct grid connection benefit from load management strategies that make it possible to charge the entire fleet within the available grid limits.

These direct to grid connections consist of common electrification connections and may be low or medium voltage and are often within enclosed or outdoor secondary substations. Applying a modular architecture approach enables greater enhancements and flexibility.

This approach provides a scalable solution that can be expanded as capacity changes. Integration of power, control and communication makes expansion quick and easy. Factory assembled, pre-wired and pre-tested solutions enables smooth start-up and reduces schedule risk. A repeatable design with local utility homologation will allow for quick connections and may be 60% faster installation and start-up while minimizing site can civil works.

The direct grid connection solution architecture can also be provided with asset condition monitoring for efficient service and maintenance including energy management for optimum energy usage and to minimize utility bills.

2. Depot architectures with on-site power generation

Charging EVs can significantly increase electrical distribution loads resulting in load imbalance, voltage drops, increased peak loading, increased harmonics, total power loss, and higher operating costs.

Installing on-site generation such as PV solar arrays can reduce the total disruption of the charging station by intermittently charging on-site storage, curbing power demand, or selling excess power back to the grid.

By installing on-site power generation technologies, fleet operators can significantly reduce their demand on the grid, thereby reducing their operating expenses.

On-site generation is also a suitable solution for:
- Charging stations that are located remotely
- Charging stations in areas with an unreliable power grid

On-site power generation solutions can be configured to meet the specific needs of any depot, based on a site energy study that considers existing infrastructure and future demand loads.

Solution architects will work with solar providers on electrical distribution needs to design and enable the required infrastructure in accordance with local regulations and requirements. The chosen configuration will be optimized for cost savings so that fleet operators can start earning returns on their investment as quickly as possible.

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11 Optional integration of BESS (Battery Energy Storage System) with solar generation

3. Depot architecture with energy storage

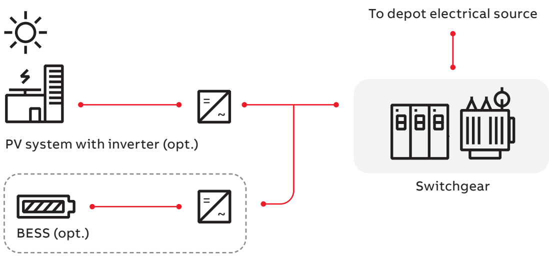
Depending on the power demands and available infrastructure for the site, an energy storage solution may be necessary to enable charging from unreliable electrical grids or in remote locations.

A solutions architect can determine the optimal battery system that will suit the fleet power requirements, with the chosen BESS solution being assembled in a factory and tested for safety and local regulations. These modular solutions are then packaged in semi-transportable enclosures with standardized connections to significantly reduce start-up time and installation risks.

There are many advantages to choosing a battery energy storage system as part of a depot architecture:

- Fine-tuned synchronized charging - a specific peak saving algorithm capable of exactly matching the peak request coming from high power EV chargers. This mitigates possible transformer overload and avoids premature aging of insulation, while also saving on utility costs
- For EVs that require additional en-route charging in remote locations, a BESS can enable higher power charging compared to the grid
- Energy storage can be connected to Photovoltaic (PV) generation and store the energy coming from daylight for use when charging vehicles overnight
- A BESS can provide power quality services, like harmonic distortion mitigation or power factor correction

Optional renewables and BESS grid support



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4. Digitally integrated depot architectures

Solutions architectures can be equipped with digitally enabled infrastructure that supports remote monitoring and predictive maintenance. These systems can be used to monitor the state of the infrastructure, diagnose and troubleshoot potential issues, and prevent potential hazards associated with in-person inspection of equipment.

By utilizing cloud technology and remote support, fleet operators can be assured that their system is operating within specification. Additionally, through advanced diagnostic software, the periodic downtime for routine inspection can be avoided in favor of predictive maintenance of the equipment.

Intelligent energy management systems
Additional benefits are possible with intelligent energy management systems that can enable optimal utilization of grid power, renewable power, and power from energy storage.

For sites with digitally enabled chargers, the energy management system can monitor load demand and the grid's electricity pricing structure and control the power delivered to the fleet to avoid costly demand charges.

An energy management system combined with on-site generation can perform a similar optimizing strategy to maximize fleet utilization of the solar PV.

Energy management, when coupled with on-site generation and battery energy storage, can maximize cost savings by storing locally generated energy for utilization by the fleet, curbing peak demand costs from the grid.

Modern systems can even forecast renewable energy generation and charge the BESS during off peak hours to avoid costs a day in advance.

Success story
Hamburger HOCHBAHN AG

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12 EV depot example with electrical distribution eHouse mounted on the roof to save space and illustrate a retrofit option

Customer: Hamburger HOCHBAHN AG

Goal: The City of Hamburg plans to cut CO_2 emissions in half from 1990 to 2030, in large part through the development of e-mobility initiatives, via a total electric fleet. Hamburger HOCHBAHN AG made its own supporting declaration, to turn its fleet of 1000 buses completely CO_2 neutral by the same date.

Project results: 30 percent space saving, reduced project timeline, modular and scalable design. With a fixed goal to completely electrify its bus fleet by 2030, Hamburger HOCHBAHN AG worked with ABB to achieve its first critical steps – the infrastructure for electrification of over 40 buses at its Hamburg Alsterdorf site.

ABB used a complex methodology of considerations to design an entire infrastructure (setup) for over 44 ABB Type HVC 150C chargers, that would be used overnight to fully charge the fleet of buses.

Retrofitting an existing facility always comes with challenges. For this site, the key difficulty was footprint constraints – a challenge which many sites will face in the coming years.

Careful consideration of the site and electrification needs led to a modular solution, including mounting the high-power chargers to the roof of the carport building. The rooftop location provided added convenience and saved ground space for the customer.

The high-power overnight charging architecture delivered an intelligent and cost-effective solution to charge the large fleet of electric buses during the night, ensuring zero emission transportation during the day.

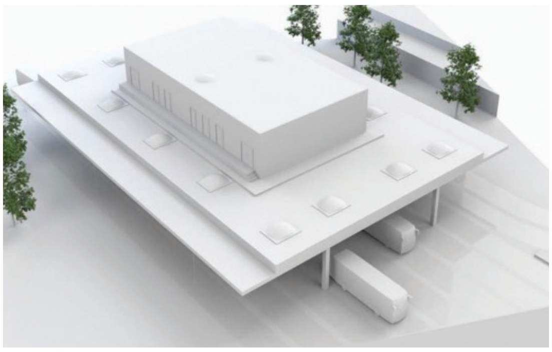
Digitally enabling the fleet
The customer was keen for the entire system to coordinate in unison and be digitally enabled for data collection and asset performance management.

ABB systems are easily connected to automated control software and in this case, was connected to the site's new energy management system (EMS). The digital architecture diagram, shown below, illustrates how the entire charging system is monitored and controlled in real time.

By utilizing the pre-engineered solution architecture approach, the customer was able to save up to 30 percent on space, significantly reduce the project timeline and minimize overall project risk. The operators of Hamburger HOCHBAHN AG now plan to extend the charging infrastructure in this and other sites in a similar design.

Side view

Top view



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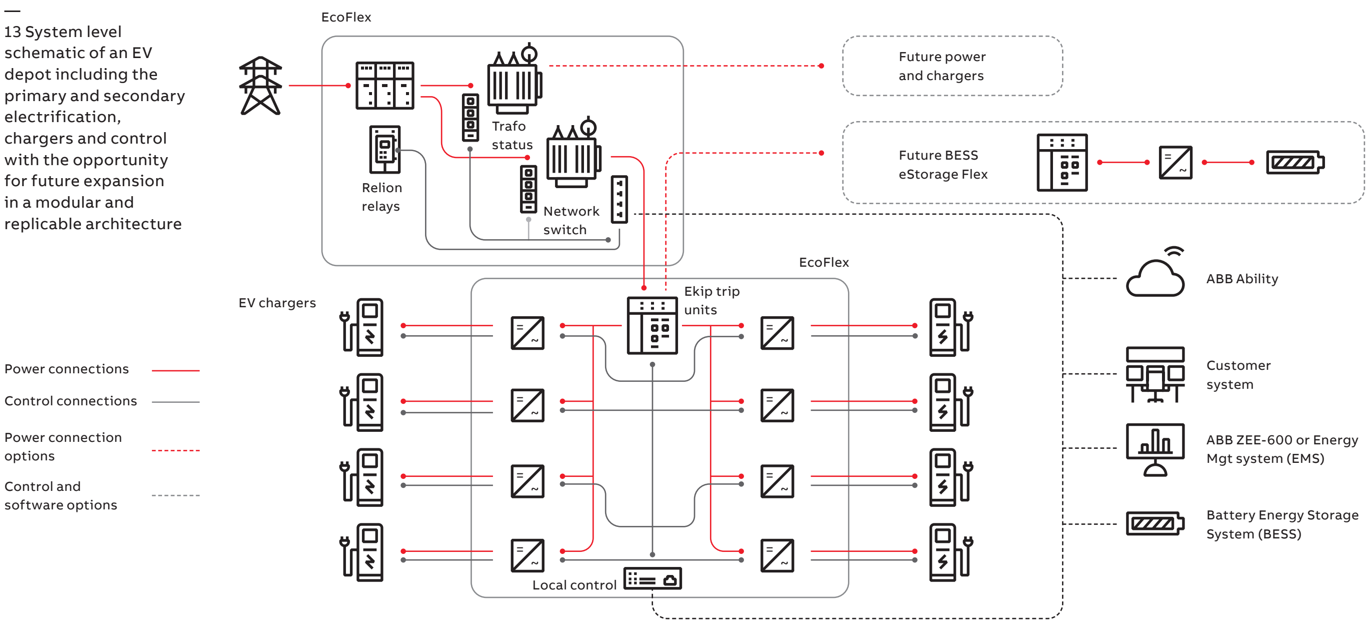
13 System level schematic of an EV depot including the primary and secondary electrification, chargers and control with the opportunity for future expansion in a modular and replicable architecture



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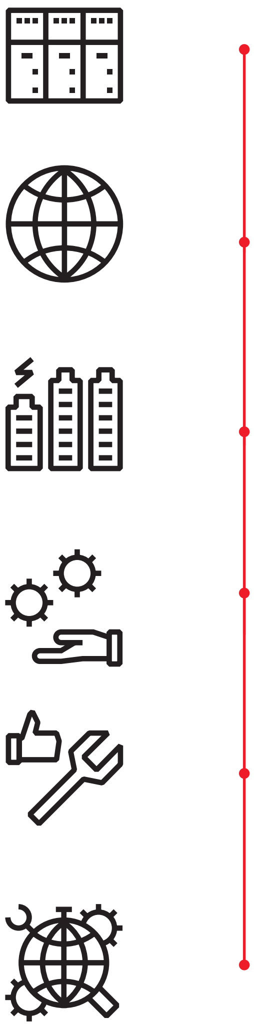
Solution architectures
A roadmap



Electric fleet power assessment and charging schedule
- Charging power requirements of the fleet determined
- Charging schedule determined

Site assessment and power study
- Assessment of existing infrastructure on-site
- Electrical grid tie-in power limits determined
- Coordination with regional authorities

Designing depot charging system
- Component selection
- Power distribution design
- Optimized on-site generation and energy storage configuration

Factory assembly
- Component assembly and wiring
- System and regulatory compliance testing

Installation
- System arrives in transportable enclosure
- Standard cabling and connection for fast and safe install
- Quick start up

Digital layer configuration
- Power management system brought online
- Remote monitoring system configured
- Charging management configured

Key takeaways

For fleet owners, taking the road to total electric is not a question of “should we?”, it is a question of “when and how will we?”.

Proper planning and considerations beyond just the vehicles and the point of charge are crucial in the success and cost efficiency of electrification, and solution architectures can simplify the deployment of depot charging infrastructure.

Solution architectures can:

- Remove much of the guesswork and technological uncertainty associated with electrification
- Identify the right power source combinations, technologies and systems for each depot depending on site requirements and the needs of the fleet
- Save time and money on the design and installation of depot charging architectures
- Ensure any depot is compliant, efficient, and delivering ROI quickly
- Offer infrastructures that are scalable, modular, repeatable and even stackable

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