Update on DC voltage

December 2020

■ Charging infrastructure

This report has been commissioned by RVO at the request of TKI Urban Energy

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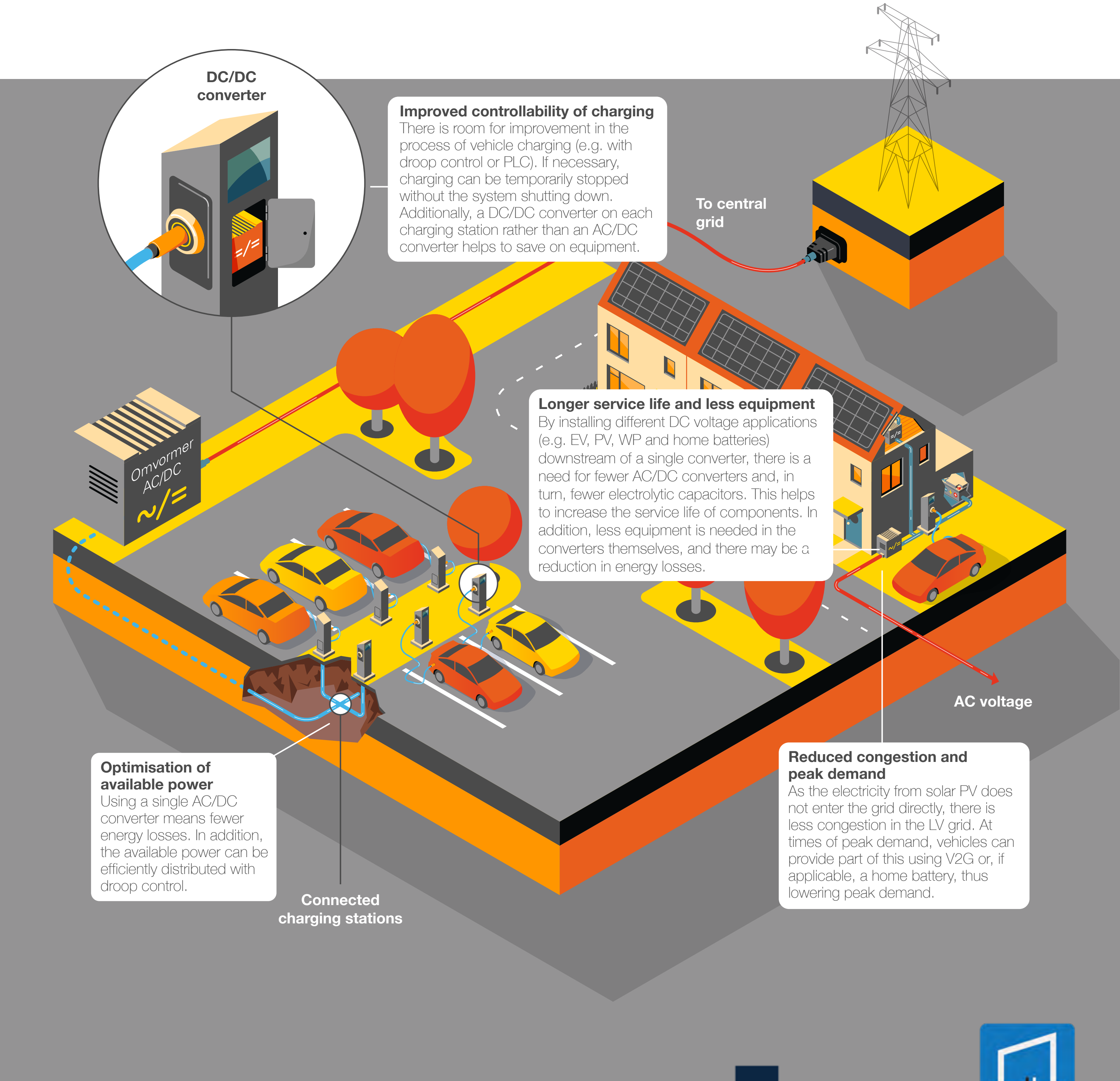

Berenschot
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Rijksdienst voor Ondernemend Nederland
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DC voltage in the charging infrastructure

DC voltage applications in the charging infrastructure can help to reduce energy losses, save on equipment and increase service lives as well as facilitate a response from the charging infrastructure to the load on the grid. DC voltage application in the charging infrastructure faces a number of difficulties, namely: (1) the current software used in electric vehicles, (2) the availability and cost of components and (3) the generation of a level playing field in tenders. It is recommended that investigations be focused on fast charging technologies, on the difference between DC voltage and AC voltage in V2G and on offering flexibility in tenders for DC voltage. We look at these aspects in more detail below.

Background

This white paper is part of a report on the current state of affairs of DC voltage in the Netherlands. The report is an update of the DC Voltage Roadmap, which was compiled in 2018. General information and details about the benefits, drawbacks and challenges of DC voltage are explained in the appendix update on DC voltage. In addition to the update on DC voltage, we also look more closely at five specific market segments by means of five white papers. In this white paper, the market segment that we will focus on is DC voltage applications in the charging infrastructure for electric vehicles. We will start with the concept, then look at the state of affairs, market adoption, difficulties and recommendations.

Introduction

The implementation of DC voltage in the charging infrastructure can be expanded and lead to a reduction in conversion losses and to control of energy flows. The energy transition and the targets set out in the Climate Accord have led to an increase in the use of electric vehicles. These vehicles are DC voltage applications, which can be charged in two ways. With AC voltage, they can be charged slowly by the converter fitted in the vehicle; with DC voltage, they can be charged both quickly as well as slowly. In the latter case, the conversion takes place outside of the vehicle, and the charger is connected directly to the battery. Looked at from a purely technical perspective, conversion outside of the vehicle is particularly interesting as it can be carried out more quickly, with more capacity over the cable. Electric vehicles are (almost always) fitted with an AC/DC converter in the vehicle as the battery always needs to be charged with DC voltage. This allows the vehicle to be connected to both an AC voltage and a DC voltage charging station. Fitting the converter outside of the vehicle enables more rapid and, in many cases, more efficient charging. Most public charging stations and home chargers are, however, AC voltage charging stations, which are cheaper and offer more limited charging speed. Consequently, a DC voltage charging station with a single efficient AC/DC converter, offers benefits for, inter alia, fast charging. The use of fast charging can be coupled with other DC voltage applications to boost the benefits. In view of the above, there are two promising concepts:

- **Concept 1. Local DC voltage micro-grid with smart combination of solar PV and electric vehicle**

The first concept is a local DC voltage micro-grid with a smart combination of solar PV and vehicle-to-grid (V2G). In this concept, a DC voltage grid for charging electric vehicles in the built-up environment is linked to solar panels and, potentially, a (home) battery. This concept is illustrated in Figure 1. The smart link offers numerous benefits:

Firstly, the electricity generated by PV panels is used directly to charge the electric vehicle or stored in the home battery by means of a direct connection to the PV panels. This will be of particular interest to grid operators, as it will help to limit the peak of solar energy that enters the grid during the day, reducing congestion in the public LV grid (1).

In addition, this link also means that fewer AC/DC converters are needed— AC/DC converters tend to be expensive and sensitive components. In this concept, only one AC/DC converter is needed—situated between the DC voltage grid of the PV panels and electric vehicle and the AC voltage grid in the remainder of the house. This reduces energy losses and requires less maintenance and equipment (2).

Additionally, electricity consumption from the regular grid is lower and 'behind-the-meter' consumption higher (3). By connecting to an electric vehicle (V2G), the peak demand in the grid from heat pumps and electric cookers can (partly) be met by discharging the vehicle. This offers considerable potential for avoiding grid congestion in the future. This effect can be boosted if consumers can connect a home battery to the DC voltage grid, alongside their electric vehicle. This concept will become of greater interest to consumers when the 'netting scheme' is removed or cut back and/or prices for peak demand electricity are increased.

Figure 1 Local DC voltage micro-grid with smart combination of solar PV and V2G

- **Concept 2. Efficient fast charging with a DC voltage charging hub**

The second concept is the charging hub concept (such as a car park), where several fast chargers are connected to a DC voltage grid, as shown in Figure 2. This means that only one AC/DC converter is needed for multiple chargers, which is more efficient than conversion on a charger by charger basis and, with sufficient scale (more than ~6 fast chargers[1]), cheaper as well. There is also room for equipment savings (1).

From a financial perspective, this is an interesting concept as chargers currently have a limited depreciation time and are relatively expensive. To reduce investment costs, the ability to purchase chargers at lower costs is of interest. As DC/DC chargers do not need a converter, they can be produced more cost effectively and are much more efficient (estimate 4%). In this application, the converter is more expensive as it is larger, but starting at six chargers, this cost is no longer a factor on account of the savings per charger. In addition, this application can also use a converter that has been used for many years on the railways and which, therefore, has a low investment risk and high efficiency. It is also of interest from a technical perspective, as there are fewer energy losses and more efficient distribution of available power within the DC voltage grid overall (2).

Additionally, the improved controllability for vehicle charging is also an interesting benefit for large squares, giving large charging hubs a balancing role in the system. If required, charging can be temporarily stopped without the system needing to be shut down. Moreover, with a charging hub, the available power is distributed among the vehicles being charged, which means that the charging hub does not need to be configured for peak power (sum of peak power per charging station). In many cases, the square will not be completely full—if it is, charging will be slightly slower.

Large charging hubs for buses may also be of interest for large V2 applications. Charging hubs for buses have a high density of electricity storage with a high power demand. Additionally, energy flows can be more smartly controlled between buses—actively using power-line communication or passively using droop control. The charging hub can also be used as control capacity for the electricity grid in the event of an imbalance.

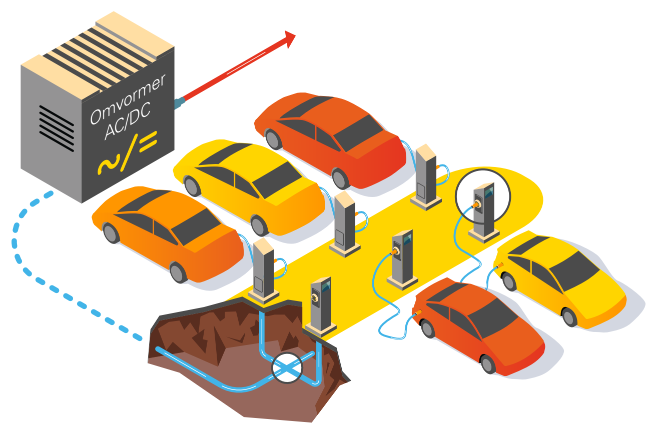

Figure 2 DC voltage charging hub

1) Indication based on interview

Areas of overlap with other market segments

- **Residential and non-residential buildings**

The first concept with V2G and the potential combination with PV panels and home batteries is in residential and non-residential buildings. In the concept as outlined above, this will be a stand-alone application with just a single connection in the meter box. The stand-alone DC voltage grid could, however, be connected to additional DC voltage applications in the home. In the 'Residential and non-residential building', white paper, this is referred to as an AC/DC hybrid grid. This could be further expanded into a full DC voltage grid, into which the V2G-concept is integrated. The benefits of the concept can be enhanced for consumers, but this would go hand in hand with an increase in the complexity of the application.

Project name	Project	Link to other technologies	Organisation	Subsidy	Type	Year (start)
DC charging hub pilot	Technical design and development of new revenue models for DC voltage charging hubs	Test with batteries, solar PV and connection to GVB tram network	University of Amsterdam/ Allego/Ecotap/ Time Shift energy storage	Flexible energy infrastructure	Pilot	2018
Smart charging hub Culemborg	Charging hub in combination with PV panels where, depending on supply and demand, smart charging and feed-in can take place	Solar PV			Demonstration	2020
Future-proof energy grids through power quality improvement for electric transport	Investigation into the effect of large numbers of electric vehicles on power quality.		ElaadNL	Flexible energy infrastructure	Feasibility study	2019
V2G Wallbox	Links PV panels to a 10 kW (DC) bi-directional charger. In a DC voltage grid	Solar PV/ batteries	Venema	?	Already available	2020

Table 1 Projects with DC voltage applications in the charging infrastructure

- **Local DC voltage grids**

The second concept (charging hubs) can be linked to local DC voltage networks. Once expanded, these squares will be consistent with the concept of local low-voltage DC voltage grids with a specific application. Combining the DC voltage grid with fast chargers allows the benefits of both segments to capitalised on.

Current state of affairs

As demonstrated in Table 1, there is only a limited number of projects involving DC voltage in the charging infrastructure. All fast chargers are—of course—DC voltage applications, but only those projects where these are connected to a DC voltage grid are stated here.

Market adoption

The 2018 DC Voltage Roadmap outlines timelines for the market adoption of DC voltage in different market segments. Figure 3 shows the timeline for DC voltage in the charging infrastructure. In some locations, fast charging already makes use of DC voltage, so it could be argued that the technology is 'market-ready'. This shifts the status of the technology forwards on the timeline. Still, the concepts outlined remain in development and are in line with the timeline.

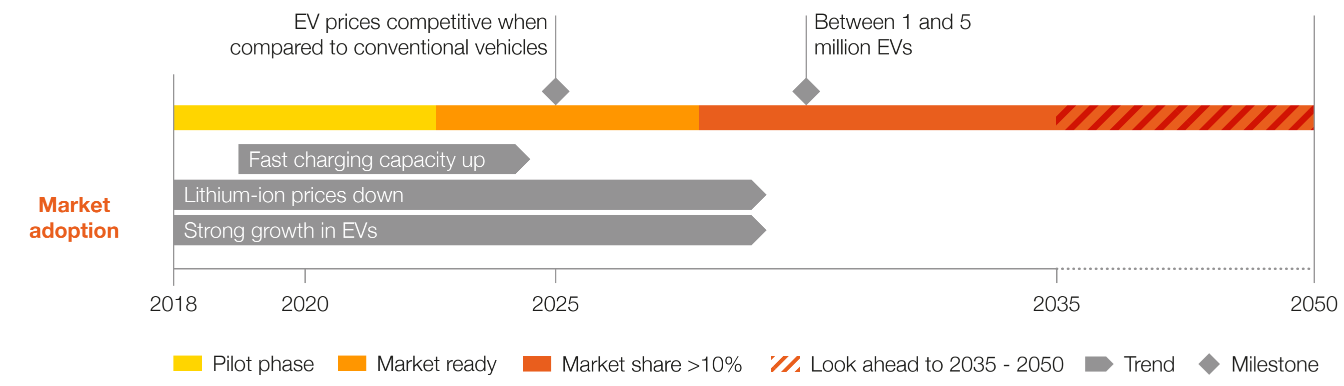

Figure 3 Timeline for charging infrastructure from DC Voltage Roadmap

Difficulties

Several difficulties have been identified in respect of the further development of DC voltage in the charging infrastructure. There are several general difficulties relating to DC voltage, such as standardisation, safety and knowledge— these are examined in detail in the overarching document entitled 'Update on DC voltage'. The specific difficulties for the charging infrastructure are the software used in electric vehicles, availability and component costs, and a level playing field in tenders.

- **Electric vehicle software (1)**
  For the application of V2G, electric vehicles must be able to charge and feed in bi-directionally. Not all vehicles are capable of doing this yet, as the software used in many vehicles has not been configured for it. There would, therefore, need to be a software adaptation to enable the integration of electric vehicles into V2G.

- **Availability and component costs (2)**
  The components used for these applications, such as the DC/DC chargers, are non-standardised. Consequently, there is no significant market competition and interested parties can only purchase them from a single party. The limited supply creates a threshold for those considering DC voltage, primarily because interested parties have no freedom of choice when it comes to the supplier, while they do with AC voltage. Consequently, interested parties tend to opt for AC voltage.

- **Level playing field for DC voltage in tenders (3)**
  Government tenders are often limited to AC voltage. Parties offering DC voltage are often at a disadvantage when it comes to competing in government tenders, even though they are capable of delivering the same service. This limits the development of DC voltage in the charging infrastructure.

Recommendations

A number of parties are already working on DC voltage for charging electric vehicles. It is recommended that the focus be more on developing standardisation. This is of relevance to several market segments and is examined in detail in the Update on DC voltage. Additionally, it is also noted that there are still too few demonstration projects. Two specific projects are recommended: an investigation into fast charging and an investigation into how DC voltage in combination with electric vehicles can contribute to the supply of electricity at times when there is no sustainable generation. In addition, it is also recommended that tenders offer the flexibility to include DC voltage.

- **Investigate fast charging technologies (A)**
  There needs to more investigation into fast charging technologies. Every vehicle is currently fitted with a converter, but due to their size, these converters are not efficient, and they must always be taken along. Increasing availability of (fast) charging on DC voltage grids, creates the potential for a steady disappearance of onboard converters. This will help to improve efficiency and provide for more space in vehicles where a converter is no longer needed.

- **Pilot on the difference between DC and AC voltage in V2G (B)**
  Additionally, the added value of a V2G system on a DC voltage grid needs to be thoroughly investigated. As outlined above, DC voltage in a V2G system can, in theory, provide ample added value. This has not yet been proven in practice. A pilot in which the V2G system on DC voltage is compared with AC voltage would clearly demonstrate the benefits of DC voltage.

- **Flexibility in tenders for DC voltage (C)**
  When it comes to public tenders for charging infrastructure, there is often little flexibility to include DC voltage technology, thus preventing the further development of DC voltage technology in charging infrastructure. It is therefore recommended that public tenders for charging infrastructure allow AC voltage and DC voltage to compete transparently.