Update on DC voltage

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■ Local DC voltage grids

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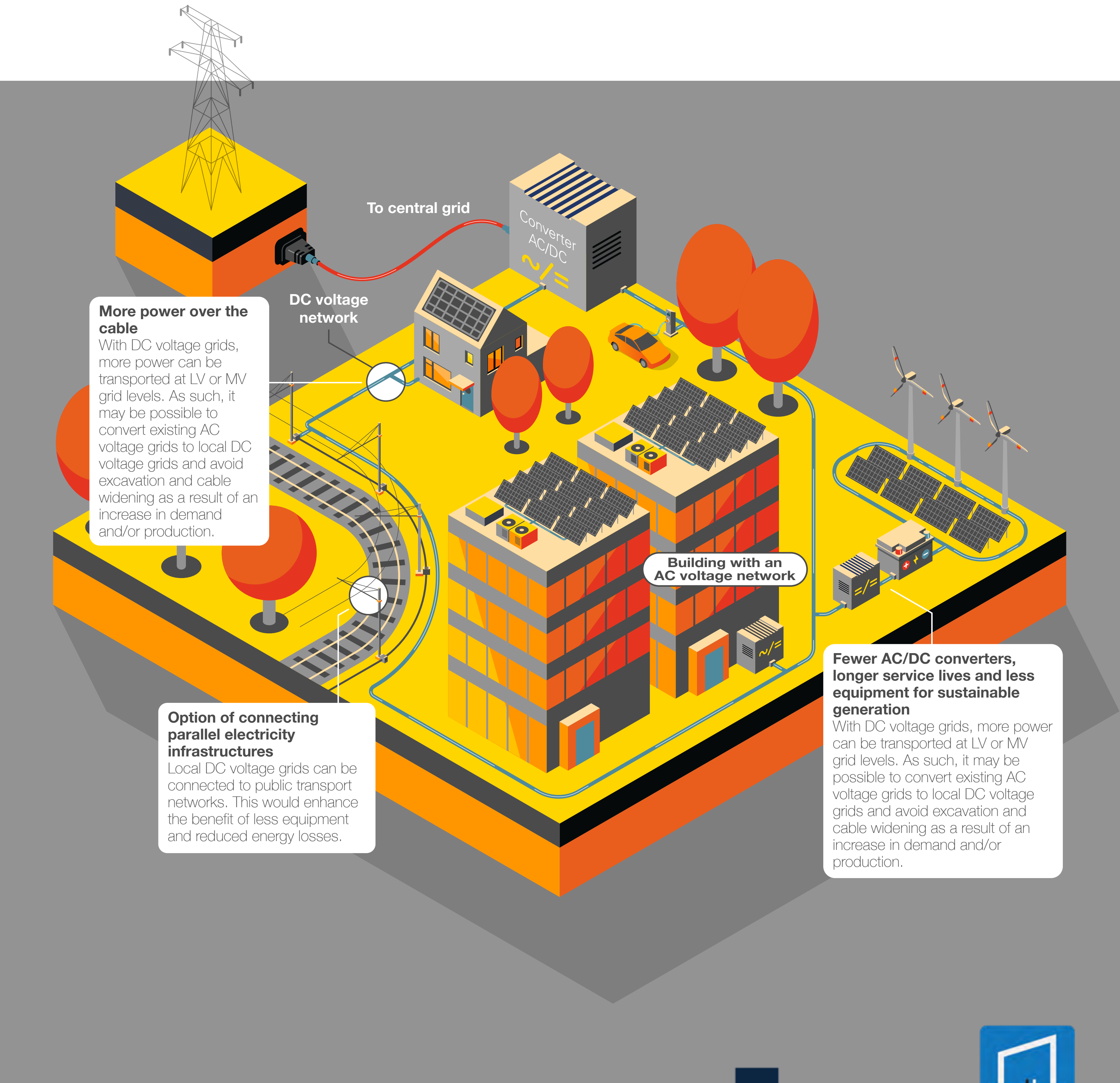

Berenschot
TKI URBAN ENERGY Topsector Energie
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Contents

DC voltage in local DC voltage grids

DC voltage applications in local DC voltage grids have the potential to reduce energy losses and optimise use of existing and new grids, thus saving on equipment. There are, however, a number of difficulties associated with the adoption of DC voltage in local grids, namely the lack of (1) a social cost/benefit analysis, (2) chain integration, (3) room for experimentation and (4) recognised measuring equipment. It is recommended that room be created for experimentation, that an independent social cost/benefit analysis be carried out and that a demonstration project be carried out, involving the whole chain. 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 local DC voltage grids.

Introduction

Grid operators increasingly face difficulties with the capacity of the LV (low voltage) and MV (medium voltage) grids. This is a problem in both urban and rural areas. In the built environment, this can be attributed to factors including the growth of sustainable PV generation, the electrification of heating and cooking and the charging of electric vehicles, which all require more power1). In rural areas, solar farms and wind turbines are generating an ever increasing amount of sustainable energy, leading to congestion. Already, grid operators are finding that they are unable to connect solar farms because the grid is unable to cope2). The expectation is that this scarcity in grids will also play a role in residential districts and industrial estates. DC voltage grids could offer a solution to these problems.

DC voltage grids have the potential to transport more electricity along the same cable. This white paper examines the following concepts:

1) Berenschot (2020): Climate-neutral energy scenarios 2050
2) Energeia: New bottlenecks in regional grids are beginning to emerge, from north to south. David Duijnmayer, September 2020

Concept 1. DC voltage grids in the built environment
The first concept is a DC voltage grid in the built environment, as shown in Figure 1. The application of DC voltage means that more power can be transported over the grid levels. Existing AC voltage grids can be converted to DC voltage grids, removing the need for excavation to allow for cable widening (1). In addition, if the DC voltage grid is connected to DC voltage applications, less equipment will be needed. Additionally, there is a reduced need for maintenance and, potentially, fewer energy losses. Parallel energy infrastructures might also be considered, such as a connection to public transport grids (2) (such as tram, trolley bus and train grids). Within this concept, homes or businesses are also supplied from a central DC voltage grid. These might be buildings running on AC voltage, where the power from the DC voltage grid is inverted to AC voltage in the meter box. This would remove the need for the building to be fitted with DC voltage apparatus (3). If those connected buildings also have an internal DC voltage grid, there is the potential for more applications, without the need for inversion, in which case the benefits will be greater.

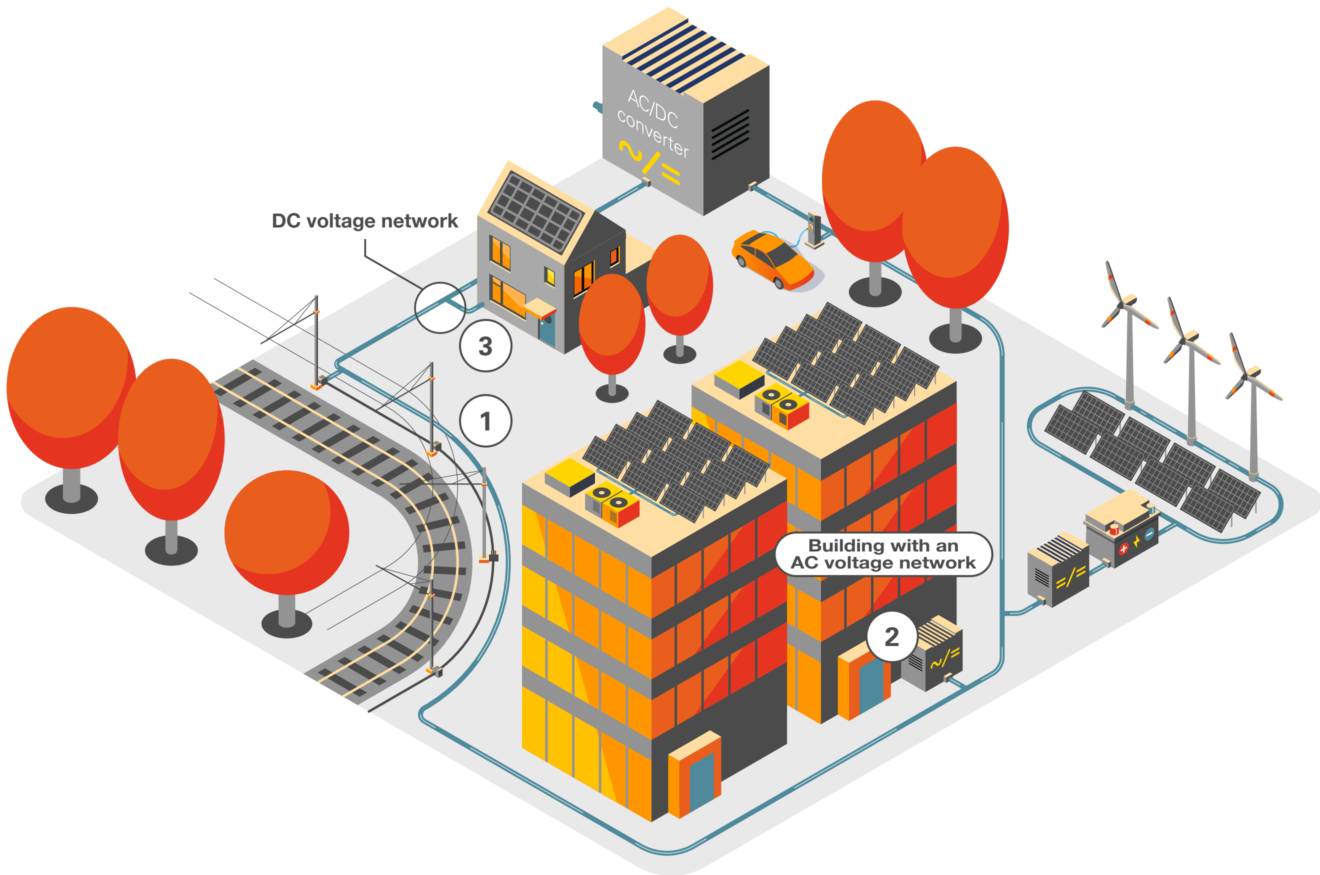

Figure 1 DC voltage grids in the built environment

Concept 2. Connect sustainable energy to the shared DC voltage grid
In the second concept, wind turbines and solar farms are both connected to a DC voltage grid before connection to the LV/MV grid, as shown in Figure 2. With this form of connection, the connection to the grid can be smaller than if everything were to be connected individually, due to the partial lack of concurrency of solar and wind energy (1). Additionally, this has the benefit of there potentially being fewer losses—the inversion from DC to AC then takes place at a central point instead of within each application separately. The initial inversion of the AC voltage from wind turbines to DC voltage will still take place on an individual wind turbine basis due to the difference in frequency (2). With solar energy, this application eliminates the need for DC/AC inverters (3), thus saving on equipment. Additionally, the service life of DC/DC converters is longer than that of AC/DC converters. The reduction in the number of AC/DC converters also contributes to increased component service lives in the grid.

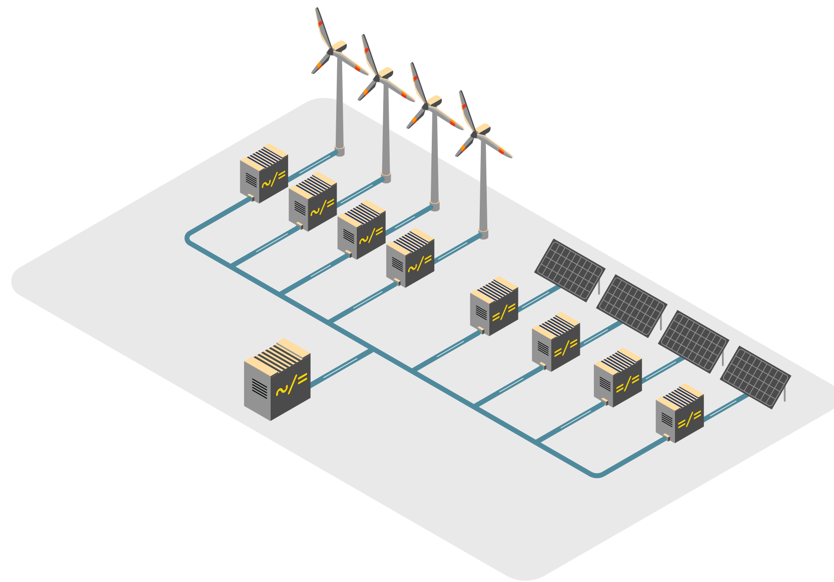

Figure 2 DC voltage grid for sustainable energy generation

Areas of overlap with other market segments

- **Residential and non-residential buildings**
  Local DC voltage grids overlap with the DC voltage in the residential and non-residential buildings market segment.
  A situation in which both the local grid and the house work with DC voltage internally has the additional benefit of reducing the need for an AC/DC converter. In this regard, developments in one segment can stimulate developments in the other. As a final overlap, both segments feature complexity due to different users. In residential and non-residential buildings, these users are the apparatus that, in the case of an internal DC voltage grid, must all be suitable for a DC connection. In a local DC voltage grid, these are all connected parties (businesses/residences) that all require a converter. This problem is of lesser significance when wind and solar farms are connected to DC voltage (concept 2).

Current state of affairs

As demonstrated in Table 1, there is only a limited number of projects involving DC voltage applications in local DC voltage grids. The business park in Lelystad and the DC voltage grid operated by Eaton are both still in the early stages of experimenting and demonstrating the possibilities of DC voltage in local grids. The project in Lelystad is a project by Liander that has been made possible thanks to a (thus far) one-off exemption from the the ACM (Authority for Consumers and Markets) for experimentation. However, due to developments in the business park being postponed, only a few applications and connections have so far been experimented with. Eaton's demo park is still in the upstart phase, during which contact is being made with parties and subsidy opportunities are being sought.

Project name	Project	Link to other technologies	Organisation	Subsidy	Type	Year (start)
Eaton DC voltage demo park	Demonstration grid to test the application of DC voltage at 700 V and involve multiple parties	Solar PV/storage/ electric charging/ lighting	Eaton		Demonstration	
Business park Lelystad	Experimental public DC voltage grid in Lelystad granted exemption from ACM	Lighting/ businesses	Liander		Experiment	2018

Table 1 Projects with DC voltage applications in local DC voltage grids

Market adoption

There has been little progress in local DC voltage grids in recent years. The market adoption of local DC voltage grids is progressing according to the picture outlined in the Roadmap. This market segment is not expected to be market ready for some time.

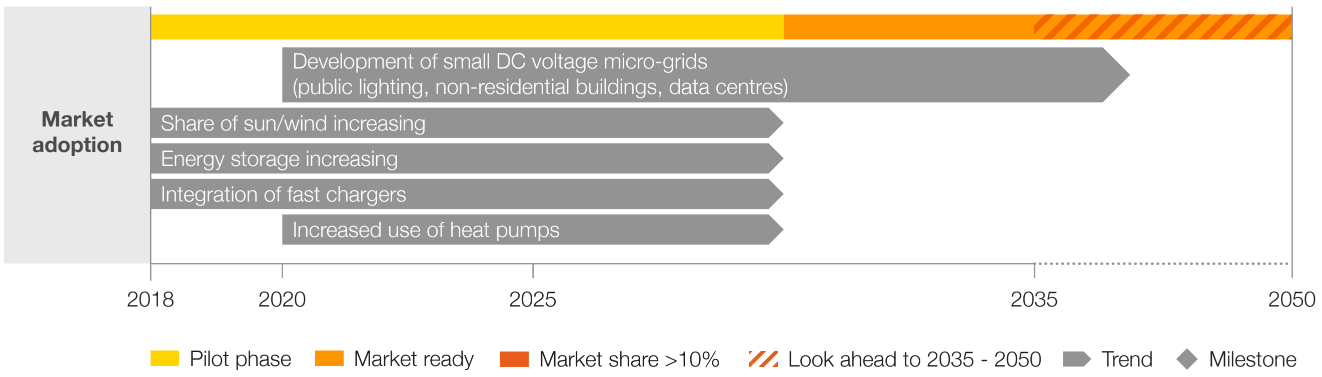

Figure 3 Timeline for local DC voltage grids from DC Voltage Roadmap

Difficulties

Local DC voltage grids face a number of difficulties, which make it difficult for innovation to get going. The key difficulties are the lack of room for experimentation, developments throughout the chain, the lack of a social cost/benefit analysis and the lack of recognised measuring equipment.

- **Lack of a social cost/benefit analysis**
  It is expected that DC voltage grids will be able to solve congestion problems, as more power can be transported over the same cable with DC voltage grids. This means that less excavation is required in order to reinforce existing grids.
  In theory, this is something that grid operators can greatly benefit from. No social cost/benefit analysis has yet been carried out to demonstrate this theory, however. As a result, the concepts remain intangible and difficult to illustrate. An investigation could look at: What are the differences in cost for grid operators between excavating the ground at LV level and visiting everyone's home to install DC/AC inverters? Is DC voltage worthwhile primarily for new networks, or also for modifications to existing networks? What is the added value of DC voltage in LV, if any, when compared to MV grids?

- **Lack of room for experimentation**
  Local grids are managed by national grid operators. These grid operators are responsible for providing a stable service and are judged according to their security of supply. The ACM gives them little room to experiment. This is also the case with DC voltage. The ACM has allowed a single pilot to be carried out as a major exception, stating that this would be the only DC voltage pilot for grid operators. Consequently, there is no motivation for grid operators to investigate local DC voltage grids.

- **Lack of chain integration**
  There are very few parties offering the components required in a DC voltage grid. As a result, those designing grids cannot always obtain the components required and must devise an alternative solution. It is, therefore, important to integrate electronics manufacturers into the process during a pilot. This is not currently happening. Once it does happen, specific components can be designed for the DC voltage grid, whereupon the DC voltage grid can be created as was intended in the design.

- **Lack of legally recognised measuring equipment**
  There is currently a lack of certified and legally recognised measuring equipment to measure the quantities of electricity supplied in a local DC voltage grid. If a local DC voltage grid were to be implemented in a large business park or residential area, it would not currently be possible to measure how much electricity each customer is using. This creates problems with billing.

Recommendations

Local grids are less advanced in development in terms of DC voltage applications when compared to other market segments. This is primarily because there is hardly any experimentation with local DC voltage grids, especially where electronic protection is concerned. Consequently, the impacts of a local DC voltage grid have not yet been properly investigated and demonstrated. Room to experiment, carrying out a social cost/benefit analysis and involving the entire chain will ensure that the potential of local DC voltage networks can be carefully defined.

- **Room to experiment**
  As indicated in the section on difficulties, there is currently little room for grid operators to experiment with DC voltage. Due to increasing congestion in the grid, DC voltage could prove to be a solution for grid operators. It is recommended that grid operators be given more room to experiment with local DC voltage grids. There is also potential for a connection to charging hubs for public transport. The validation session indicated that major benefits are being seen in the application of DC voltage in distribution grids (as illustrated in this paper). At the same time, participants also suggested that grid operators are not particularly focused on this topic. Accordingly, it is recommended that the opportunities offered by DC voltage be put on agendas and made explicit within the context of, inter alia, the energy transition.

- **Calculation of independent social cost/benefit analysis**
  No social cost/benefit analysis has been carried out to examine the differences between an AC voltage and a DC voltage grid. Thus far, the focus has primarily been on (initial) costs and potential risks. If social factors, spatial impact and sustainability are incorporated into the business case, for example, the choice for DC voltage may be more clear cut. A social/cost benefit analysis should therefore be carried out in order for there to be a fair consideration and to put DC voltage more on the map.

- **Demonstration projects for the entire chain**
  The lack of experimentation, chain integration and measuring equipment creates a vacuum in which there is a lack of knowledge among potential customers and a lack of components from manufacturers. To get beyond this, demonstration projects will need to be carried out, wherein the entire chain collaborates—from customer through to manufacturer. Additionally, divergent DC voltage applications, such as solar PV, LED lighting, batteries, wind and/or EV chargers, should be connected to the grid so as to enhance the benefits of DC voltage. A joint programme of this nature could be managed by TKI Urban Energy.