DC in the Netherlands

WE ARE DCIFYING THE WORLD
MAKING DC SYSTEMS BY
CONNECTING SOURCES & LOADS

DIRECT CURRENT BV
HELLAS RECTIFIERS BV
FEMTOGRID ES BV
We are already live in a DC world

Why DC

Everything we ♥ and 👍 is DC

DC brings fun, comfort, clean and sustainable solutions
ACTIVITY

Owner of the following Companies:
- DC. Systems Ltd
- Direct Current LtD
- Hellas Rectifiers LtD
- Amstel Rectifiers LtD
- Femtogrid ES LtD
- DC Hortilighting LtD
- DOE-DC LtD

Foundations
- Founder of the DC Foundation
- Founder of Current/OS Foundation

Skills
- Started in 1988 as a DC entrepreneur. Building and creating DC systems for industrial applications
- Energy systems
- Power Electronics
- High Current technology up to 30kA
- ICT firmware/software
- Grid regulations
- DC System integration
- DC Applications
- DC Industrial processes
- DC and corrosion

BACKGROUND

- Protecting the Dutch Water defense against corrosion
- Green deal Enabling a outdoor DC grid
- Universities Active in the TU/Delft supporting the faculty DC and storage

COMMISIONS

Commissions
- IEC LVDC SyC CAG1, CAG2, WPG1 Convener AhG1 LVDC SyC in the IEC for use case the last mile
- SyC LVDC liaison officer for TC8-WG9
- IEC TC 61200 PT101/102 TC64
- Convener Working group DC TC64 (NEN 1010) NPR9090
- Member electrical infrastructure of the Dutch Democrats D66
- CIGRÉ SC 6.31 MVDC distribution

CV

- Protecting the Dutch Water defense against corrosion
- Green deal Enabling a outdoor DC grid
- Universities Active in the TU/Delft supporting the faculty DC and storage

Contact
Harry@dc.expert

I’m Dyslectic, so forgive me for spelling mistakes.
DC SYSTEMS

**Contact**
info@dc.systems
+31(0)850-444 000
Oosteinderweg 127C
1432 AH Aalsmeer
The Netherlands

**Support**
support@dc.systems

**Sales**
sales@dc.systems

**Purchase**
purchase@dc.systems

**Invoices**
invoices@dc.systems

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**DIRECT CURRENT**

- **R&D**
  - Safety, Protection, system dynamics, infrastructure, negative side effects, business cases, power electronics
- **Product design**
  - Drivers, interfaces, protection, converters
- **System integration**
  - Buildings, Outdoor services, Distribution Grids, Greenhouses
- **Creating use cases**

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**HELNAS RECTIFIERS**

- **Manufacturing**
  - Address
  - Fuultaan 12E1
  - 5613AB Eindhoven
  - The Netherlands
- **Rectifiers**
  - In the range from 1 ... 30kA
    - Cathodic Protection
    - Electrochemical
    - SMPS up to 10kW @ 500A
- **Active frontends**
  - In the range from 6kW ... 1MW

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**FEMTOGRID**

- **R&D on solar**
  - Safety, Optimizing power, Fire protection, cables and connection systems
- **Micro converters**
  - For 350V and 700V DC grids
Why grids are important

• The electricity grid is one of the most value assets the society owns
• It give us:
  • Energy
  • Hygiene
  • More dense society
  • It’s the fundament of the economy
  • Solution to sustainable systems
  • Economics

• We have to protect is and make it simple as possible
• It’s not about the business case only but it’s about our continuity in life.
VOLVO INTRODUCEREN VANAF 2019 ALLEEN NOG 'ELEKTRISCHE AUTO’S'

BMW komt komende jaren met 25 modellen elektrische auto’s

3x meer elektra verbruik
Net aanpassing minimaal 7 .. 10 jaar
De groei gaat harder dan gedacht.
Future and challenges

Population Growth over the Last 500 Years
China, India, Africa, Latin America, Western Europe, and United States

- China develops faster maturing varieties of grains for use in Double-Cropping
- Four-Field Crop Rotation introduced in Great Britain
- High-yield Grains Developed

Source: Angus Maddison, University of Groningen

All electric
Copper
38 to 61 year

Raw materials and DC
In the end everything is solved

Gold - Oil - Sand age

It’s all about sand.

Gold

Cooperation

Create issues

Solve them

Oil

Sand
Everything is also possible in AC

- The discussion is not
  - Efficiency
  - Can not be done in AC

- But it makes more sense to do this in DC because
  - It’s about reduction of complexity
  - It’s about reliability
  - It’s about a full electronic system
  - It’s about predicting the system
  - It’s about raw materials
  - Having a high share of renewables in the system
  - It’s about increasing power levels in the last mile or application with smaller connections

It’s not all about system efficiency, but about an efficient system.
Control AC vs DC

Realtime Centralized Control

Smart grid

- Trust
- Privacy
- Availability
- Autonomous

Realtime Local Autonomous Control
The other society in development
DC connecting worlds together

1,2 Billion people without electrical access

- Energy
- Food
- Water reduction
- Greenhouses
- Direct Current
- Electrical cooking

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**DC in Standards**

- IEC TC 8 WG9 LVDC distribution Selecting the voltage levels
- IEC TC 64 PT101/102 Guidelines for developing countries up to 1500V
- IEC TC23E working on DC RCD
- IEC LVDC System Committee coordination between the different TC’s
- TC64 DC Workgroup (NEN1010) result NPR 9090 In the Netherlands
  - 350/700V DC as advised standard,
  - Risk labels DC Zones
  - Grounding structures
DC Zone 0 unprotected source
DC Zone 1 protection by fuses or circuit breakers high breaking currents
DC Zone 2 is current limited
DC Zone 3 and 4 are based on semiconductor protection (connect to DC Zone 1,2)
DC Zone 4A is SELV or PELV

Part of the Dutch wiring regulations
But this is not all
Effects of DC

Yesterday

Now
Projects where we are involved

• DC Flex house (Renovation and DC)
• DC in lofts
• DC in Buildings ABN and Pulse TU/delft faculty building and construction
• DC in streetlighting
• DC in tunnels
• DC in football station Amsterdam Arena
• DC public service bus
• DC in the last mile
• DC and cooling combined with solar
• DC in greenhouses and last mile
• DC and charging EV and electric busses connected to the Metro traction
• DC in industries 4.0
• MVDC roundabout in the chemical industry
DC Homes

- DC Lofts Strijp-s Eindhoven, 50kW central DC installation where multiple apartment owners are connected, USB-C, Batteries & Solar

- DC-Flexhouse where we are working on renovation of existing homes


- DC Grid for student houses in Delft just started

- DC grids in holiday parks
DC Outdoor lighting

- Outdoor (we started this because it’s innocent, but can be expanded)
  - 90 km Public lighting installed in the Netherlands with as result:
    - More than 50 new projects moved into prospect state (business case)
    - Now we talk about bringing other application to the public service grids
    - Enabling new services and possibilities where nobody has thought about
Bipolar DC grids running on ±350Vdc and 700Vdc for last mile replacement
• 3x 50kW Active Front Ends. Driving 150kW DC bus managed by the Current/OS protocol

• 535x 280W panels connected to DC micro converters

• 15x 16A/350V Current Routers protection

• 30kW LED lighting directly to DC

• 10kW Ventilation directly to 350V

• 6x 2500W AC 230V from the 350V DC

• Current/OS congestion

• Connection
  • 48x USB-C 100W
  • 48x USB-A
  • 48x 350V 10A sockets

Safety Wire for Protection 48V DC
DC and Parking

- 60 ... 600 Charging points power between 500W...10kW bidirectional start with 60 chargers
- Simple infrastructure
- Vehicle to grid
- High Safety systems can be easy disconnect for work
- Realtime congestion management
- 300x DC Public lighting  30kW
- Direct PV integration 1MW peak
- Small grid connection <600kW direct connected to the DC grid from the DNO.
- Ring grid structure
DC in Tunnels
DC and football
DC Greenhous status

- 1.5MW DC grow light blocks of 150kW @ 700V DC (tested for 1 year)
- Next step 1 MW HPS integration directly to the 700V DC grid (during 2018)
- In progress with the grid operator grounding issues and at some point move the DC connection to the grid operator (Alliander) (end of 2017)
- In progress PV installation connected to the main AC/DC station (begin 2018)

Manny hordes to take and taken
- Grounding AC and DC
- Main protection
- Active case, fall back scenario is mandate
- Converter station grid operator ready
- Limited budget for realization
- Hybrid breakers and Solid-state breakers
- Grid codes
- Installers acceptance
DC and Corrosion

• Corrosion is a underestimated issue we have more then 50 year knowledge in this area.

• We are protecting the Netherlands. The Dutch water defense systems “The Delta works“ are protected by our DC systems

• And we are very proud that our system helps the Dutch to keep their feet dry
The Why (voltage level)

Why 350V DC (320V...380V range)
- With ±30VDC Droop the limit for direct touch disconnect time = 2.5 millisecond. So can be used in Home applications. In line with the IEC60479-2
- Clear number not confused by AC voltage levels in hybrid cases
- Multiple grounding possible
- Similar design criteria's as 230V AC
- Lifetime improvement with 600/650V semiconductors
- In case for bipolar ±350V DC the 700V DC levels is available for larger power devices

±350V DC use this for locations where direct touch protection is needed.

Why 700V DC (640 ... 760V range)
- Isolation windings in motors is in the safe range
- Clear number not confused by AC
- ±60VDC droop
- Multiple grounding possible
- Similar design criteria's as 480V AC
- Lifetime improvement with 1200V semiconductors and capacitors
- In case for bipolar ±700V DC the 1400V DC levels is below the 1500V DC border this enable full range of the voltage band to use

Standardized in the Netherlands in the TC64 application paper in the Dutch NEN1010 practical guide
Questions need to be answered for selecting the correct voltage level

The voltage level including the droop ranges is defined by the:

- Grounding system
- Direct touch protection
- Distribution efficiency
- Full replacement of existing AC solutions in many applications
- Must work in all applications, with compatibility
- Clearness in hybrid systems
- Arcing
- Corrosion
- And many more small items that are common overlooked
DC system voltages

350V DC

- Power direction
- 350Vdc ±1.4% ±30V droop
- 320...380V DC
- Max. -10V...+10V
- +350V M Device

±350V DC

- Power direction
- 350Vdc ±1.4% ±30V droop
- 700Vdc ±1.4% ±60V droop
- Max. -10V...+10V
- +350V M Device
- +700V M Device

700V DC

- Power direction
- 700Vdc ±1.4% ±60V droop
- 640...760V DC
- Max. -20V...+20V
- +700V M Device

±700V DC

- Power direction
- 700Vdc ±1.4% ±60V droop
- 1400Vdc ±1.4%
- Max. -20V...+20V
- +700V M Device
- +700V M Device
- +1400V M Device
DC and Direct Touch

- Additional protection (protection against direct contact) still possible for 350 VDC nominal 320...380V including droop with a overshoot to 400 VDC.
- Pictures below according to NEN NPR 9090 Wiring regulations in the Netherlands

<table>
<thead>
<tr>
<th>Type</th>
<th>$I_n$ [A]</th>
<th>$I_{sh}$</th>
<th>Standard values of break time at a residual operating direct current equal to $I_{sh}$ (ms)</th>
<th>$I_{sh}$</th>
<th>2 $I_{sh}$</th>
<th>3 $I_{sh}$ &lt; 1 A</th>
<th>1, 2, 5, 10, 20, 50, 100 A</th>
</tr>
</thead>
</table>
| General | Any value | ≤ 80 mA | 40 | 10 | 2.5 | see NEN 1010:2015 table 41.1

Safety is in our tradition
The first historical safety shoes 😊
Current/OS Interface to DC grids

- 2kW 6A 350VDC
- Connect Devices that can work on DC to the Current/OS
- Safe connection for devices
- No inrush currents

Many devices can work directly on DC but not according the DC protocol.
DC Current Router (protection) 16A (100A version in Q4-2018)

DC protection in greenhouses
- 16A Solid-state Breaker <8us short detection
- RCD 1...80mA 0.1sec for 80..500mA <0.025sec (IEC 60479-2)
- G3 powerline communication for parametering
- RS485 SCADA control (MODBUS)
- kWh meter
- Congestion management
- Priority structure
- No inrush current
- Black start protocol
- Protection of the incoming DC
- Arc detection
- <12W losses @16A / 700Vdc incl. housekeeping and communication
- DC Zone 3 and 4 operation
DC Micro converter

Features

- Superior performance due to Maximum Power Point Tracking (MPPT) on each PV panel
- Superior MPPT efficiency >99.9%
- Electrical efficiency (97%, peak) and (95.8% euro)
- Parallel software architecture
- PV panel add-on
- Power rating 300/310W nominal, 310/330W peak
- 60/72 and 96 Cells versions (55V or 85V max input voltage)
- Droop control
- 350Vdc, 380Vdc available and 700Vdc expected in 2017
- Patented 48Vdc safety system
- PV panel level monitoring
- Monitoring level safety
- Solves the negative system impact of:
  - shading conditions
  - module mismatch
  - aging mismatch
  - soiling mismatch
  - temperature variance
USB-C 350VDC

- Wall enclosure
  - >97% efficiency
  - 100W max USB power
  - USB-C socket up to 20V 5A (100W)
  - USB-PD power protocol
  - USB-A socket 5V 1.5A
  - 350Vdc input voltage
  - Current/OS 350Vdc compatible

Next steps for 2017
- Domotica
- Current/OS Power Line Communication
- Overbooking possible
- Power delivery device to DC grid power flow UPS function
- Distributed batteries
- Highspeed Ethernet
Active frontend

- Safe DC grid bidirectional
- Isolation transformer
- Activate from the DC but
- In case of batteries UPS function
- Autarky mode OFF grid in case of batteries
- Emergency mode
- Constant Power factor = 1
- In Modules of 50kW
- 50/100/150kw Versions
- 350Vdc or 700Vdc versions
- Connection for PV systems
- Integrated System controller (ARC)
- Current/OS (voltage & communication)
- In case of multiple modules it puts itself in cascade mode. Auto stepping in steps of 50kW
- Routing PV power directly to load
- IGBT based (SiC versions 2018 for improved version)
- Width 1.2m+ (modules * 0.4m)
- Height x Depth 2m x 0.6m
- 48Vdc Safety bus for PV system
- Intern or External MS-SQL database for logging
- Power monitoring

350V model
- Up to 30 current routers
- Losses 3.5kW/50kW
- Direct connection to DC micro converters for PV up to 500 panels
- Direct connection for USB-C and LED drivers.
- PV panel to Load 97%
- PV panel to grid 91%

700V model
- Up to 30 current routers
- Losses 2.6kW/50kW
- Direct connection to DC micro converters for PV up to 500 panels
- 150kWh batteries
- PV panel to Load 97%
- PV panel to grid 92%
AC/DC Bidirectional Converter
Primality Q4-18

- Power 6kW (2x3kW)
- Voltage +/-350V DC
- 3x (2x10A) Current router
- 3x RCD
- Galvanic isolated by bidirectional DC/DC converters
- 600x220x250 mmm (HxWxD)
- 3x Zone 3 or Zone 4 Connections
- 1x AC Input Bidirectional
- Galvanic isolated DC from AC
- TN-S(CDD) grounding
- ARM Linux running Domoticz
- Power line communication
- 3x RS 485 for Zone 3 sources
- AC Protection
- Current/OS implemented
- 3x isolation switch
- 6kW natural cooling but fan needed when ambient is higher than 45 degrees
- Design lifetime 200K hour
- Overall efficiency 97.5% <40W housekeeping and active no load losses
Battery Connection
Primality Q4-18

- Power 6/8kW
- Voltage 700V DC
- 1x16A Current router
- 1x Zone 3 Connection
- TN-S(CDD) grounding
- RS 485 for Zone 3 sources
- Current/OS implemented
- 3 phase Buck Boost Max 15A battery current natural cooling
- Efficiency 99.1%
- CAN BMS Interface
- SOC optimized based on state of grid
- Easy to combine multiple batteries in one system
DC Public Lighting

Public lighting on DC
Products and system designed & invented by Direct Current BV

Management in the cloud

Example: We have installed more than 1800 Public Lights of 60W More than 90km in the Netherlands in cooperation with Eleq, Lightwell, Luminext and CityTec based on:

- ±350Vdc Grids
- Earth fault protection 1..30mA adjustable
- Cable quality and state is known
- Lighting protection
- Arcing detection
- Corrosion protection
- Fully controlled
- Smart grid (Current/OS)
- Power Line Communication G3 protocol connected to the cloud
- No Breaking Current needed for protection
- Cable length > 2km
- HVAC transmission lines area
DC and Processes

- IP67 Anodized housing and highly chemical resistance coating
- >97% efficiency
- 100% Digital using DSP’s
- Extremely low EMC
- RS485 Modbus (next step Power line communication)
- Full control by fieldbus
- Firmware can be updated
- Under and Over alarms
- Contact Failure Detection
- Auto Low Voltage
- Low product damage at shorts
- Arc prevention
- Coulomb counter (As, Am, Ah)
- Calibration during process
- PIN code to lock parameters
- Machine Builder Coding
- 700Vdc Current/OS interface
- 8V/100A or 16V/50A

Current OS

Solar production line

DC Systems
Capacitive Grounding blocks for large DC systems