Current OS
DC Microgrids
N470 road application

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1 About the Authors

Harry Stokman is the founder of DC Systems and is now a prominent employee of Schneider Electric. Harry has been a DC entrepreneur since 1988. He has been the owner and CEO of Hellas Rectifiers since 1998. He has been the founder, owner and CEO of Direct Current BV and DC Systems BV since 2009. He founded and has been chairman of the DC foundation since 2010. He is a globally recognized specialist in DC on the following topics: Control, Distribution, System Grounding, Corrosion, Protection, power electronics and High Current systems. He is the inventor of Current OS Protocol based on 350V DC and 700V DC. He received multiple awards for his work in the LVDC: Nennovation Award from the NEN (2019), 1906 IEC Award from the IEC (2018), Runner-up The Process Award from the European Commission (2016), Greendeal Award from the Dutch government (2016). He is very active in standardization bodies. He is the Convener of Dutch TC64 NEN1010 WG DC. He is the convener or member of SyC LVDC multiple TG and WG, member of some TC 8 working groups and member of multiple TC 64 working groups.

Ronald Niehoff is member of the Technical Expert Team of the Current OS Foundation. He has been working at Eaton Hengelo since 1990, starting as R&D specialist Electronics, subsequently as Standardization & System Architecture manager in the Innovation team of Eaton PMCC, located in Vienna. He owns 19 patents, mainly in (DC) circuit breakers and RCD technology. Since 2014, Ronald spends most of the time on technical business development in DC with activities around creating DC customer solutions, project calculations and DC consultancy. In addition, he participated in several projects like the N470 DC installation in Delft in the Netherlands. Ronald likes to work in multicultural-, international- and multi-company teams.

Yannick Neyret is the chairman of Current OS Foundation. He has been a Schneider Electric employee for more than 30 years with various position in strategy, marketing, and global offer creation. He influenced the digitization and automation of electrical distribution over the past 20 years with multiple innovations. He owns or co-owns about a dozen patents.

2 Electrical distribution context and new challenges

The electricity needs are increasing due to rapid growth of electrical vehicles (EV), digital and communications (IT) and heating with heat pumps. Renewable electrical sources contribute to electrification of the human activities to substitute fossil fuels.

Public electrical grids are more and more reaching their limits. Buildings, infrastructure, and industries are more and more investing in local electrical resources such as photovoltaic (PV) and battery storage systems (BESS) to ensure power availability and continuity of their business. These new electrical distribution applications in sites are also named **microgrids**.

All these new sources (PV, BESS) and loads (EV, IT, etc.) are intrinsically generating or using **Direct Current** (DC). Therefore, electrical distribution in DC seems more and more necessary to link DC sources with DC loads.

DC electrical distribution also brings new benefits such as easier control, by nature bidirectional power flows (regenerative power on motor breaking for instance) or no capacitive leaks on long distance applications.

The **power electronics** components are more and more affordable, opening the door to solid state protection devices.

3 The Current OS Foundation

Direct Current technology offers huge opportunities to contribute to human development goals such as decarbonation of energy and massive electrification of human activities by helping massive adoption of distributed electrical resources while limiting the power demand on public electrical grid.

The **Current OS Protocol** is an evolutive TOOL SET to ensure INTEROPERABILITY, safety scalability, effectiveness and trustfulness of DC multisource applications. This protocol defines all systems aspects for loads and sources such as voltage levels, protection, grounding, corrosion mitigation etc. in a CONSISTENT manner. Current OS Protocol is OPEN by nature TO ADDITIONS by different classifications of products for different use cases.

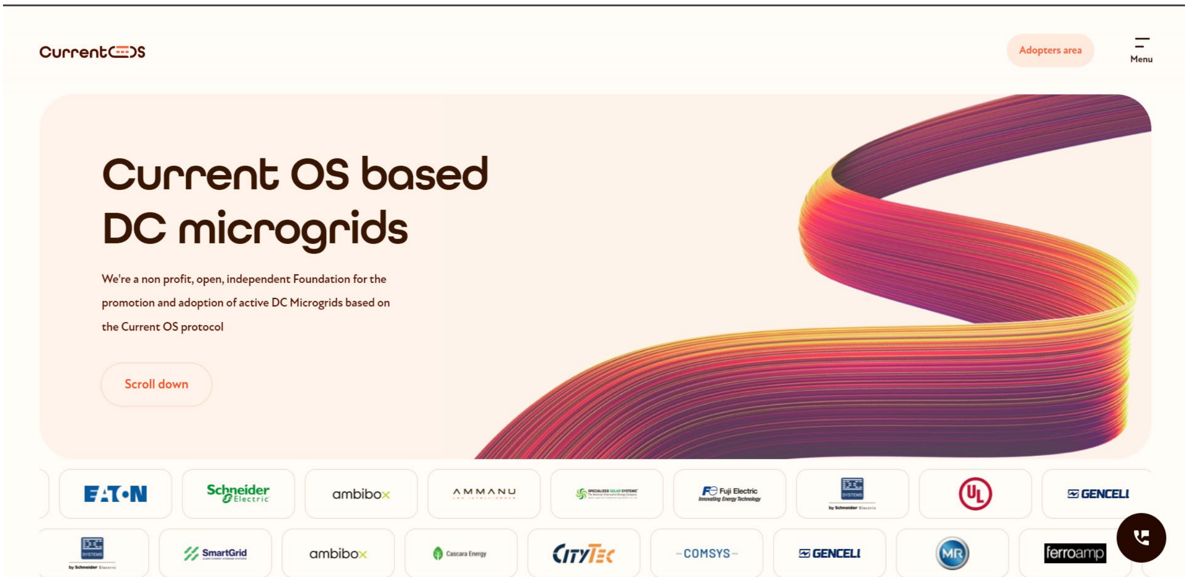
To assure the availability of this protocol to any product manufacturer, the Current OS Foundation is being set up. The **Current OS Foundation** is a non-profit, open, independent foundation aiming to ease MASSIVE adoption of safe and trustful DC multisource applications in all verticals and avoid fragmentation and confusion on the emerging market.

The Current OS Foundation provides under fair, reasonable and non-discriminatory (FRAND) terms the Current OS Protocol to the electrical ecosystem with FREE right of use of IP and clear guidelines on how to manufacture products that work in a Current OS Protocol based DC environment. It also aims to define and operate a CERTIFICATION scheme in respect of scope, competencies and stakes of all market actors. (sources and loads manufacturers, design offices and integrators, users and services providers).

The Current OS Foundation works to ensure SAFETY and effectiveness of multi sources DC applications and identify the gaps in STANDARDS and work them out to reach CONSENSUS within contributive people and teams (experts, manufacturers, research institutions).

Major electrical corporations such as Schneider Electric, Eaton, UL (and others soon coming) are supporting us to make this protocol a global standard for DC infrastructures.

Please refer to Current OS website for more details : https://currentos.foundation/



4 N470 road installation

The provincial road N470 was a one-of-a-kind project for the region, involving multiple partners. South Holland aspires to manage and maintain its roads, waterways, bridges, and locks in a carbon-neutral manner. These spectacular goals have been realized in the N470 project by creating the most sustainable road in the Netherlands, and by demonstrating to the market that **this is a normal tender within the existing ecosystem of electrical actors. This is NOT a demonstration project or a POC ("proof of concept").**

It is the first road in the region to have been renovated entirely in a CO_2-negative manner and to generate its own energy for lighting and traffic signals. Additionally, traffic can continue to flow more freely, and the road has been made safer through the use of new DC technologies. The distances are short, which prevents electricity from being lost during transmission via high-voltage cables and conversion to AC. This minimizes energy consumption and CO_2 emissions. The green battery stores the energy generated during the day so that it can be used later in the evening when the sun is not shining.

The N470 is the first to be equipped with a self-sufficient energy system. The Energy Wall is a noise barrier that also produces energy via solar panels embedded in the screen's glass plates. The generated energy can be used directly to power over 400 public lighting drivers and over 250 traffic light fixtures further down the road. The noise barrier is made up of 100kW solar and generates 75 megawatt hours of electricity per year. This is approximately the same as providing green electricity to approximately 26 households for one year.

The following are some functions of this installation:

- The system is powered all along 4.7 kilometers with only two sub-field cabinets.
- The cable is powered by DC to avoid the difficulties associated with passing AC power through a water channel.
- The system can operate in islanded mode if the public grid is lost.
- The system is an autonomous microgrid with distributed sources with managed power flow without digital communication (Current OS Protocol based system).
- The system includes power management features but does not require data or an internet connection for security reasons.
- The system is integrated with renewable energy sources such as photovoltaic (PV) and energy storage.
- It is a commercial project, not a demonstration project within the established ecosystem.
- The first DC project was developed in accordance with the Dutch technical guide for DC installations (NPR9090).

The project's technical specifications include the following components:

- The power distribution cable is 4.7 kilometers long contains a four-core cable of +\-700 Vdc with a +/-60Vdc droop control, and a TN-S earthing arrangement.
- The network is earthed using a TN-S with multiple earthing arrangement with additional stray-current protection provided by the use of diodes to separate the metallic and electric earthing.
- The solar panels are connected to the main power distribution system via DC/DC converters.
- Two active front ends of 100kW each interface with the AC public grid (If the public AC grid support is disabled the full installation will continue without any interruption in islanded mode) and operate on 50kW with limited line currents.
- Ambient requirements include a temperature range of -20 to 50 degrees Celsius and a relative humidity of 95% at sea level.
- The AC station is rated at 150kVA.
- The DC system is electrically isolated from the AC system.
- 1MWh LiFePo4 battery system based on 12 strings connected via DC/DC converters and protected by solid state circuit breakers.
- Distributed batteries equipped with autonomous system capable of communicating with the BMS and reacting to the state of the grid (SOG) in conjunction with the state of health (SOH) and state of charge (SOC).
- Streetlights connected to a network of 23 strings x ±350V with a +/-30Vdc droop control equipped with DC/DC led drivers and power line control.
- The streetlights are equipped with RCDs to protect the public against direct contact. DC public lighting installations at 350V RCD protection is possible because there is almost no DC leakage in cables. In the DC DC converters which are used for the 750VDC-350VDC conversion at the N470 already overcurrent and RCD protection is integrated. (*note : In AC public lighting installations no RCD protection is used. This is not possible because of the high leakage currents due to cable to ground capacitance. It is not required by electrical standards for this reason. So it is equally not required by standards for DC applications, but it is much safer to have it*.)
- The network incorporates hybrid circuit breakers and solid-state protection.
- Overvoltage protection is incorporated into the network, as well as Arc fault detection
- Power flow and protection, for example, are determined by the Current OS Protocol and requirements.

Reference:

https://www.zuid-holland.nl/onderwerpen/energie/energiewegen-0/n470-geeft-energie/

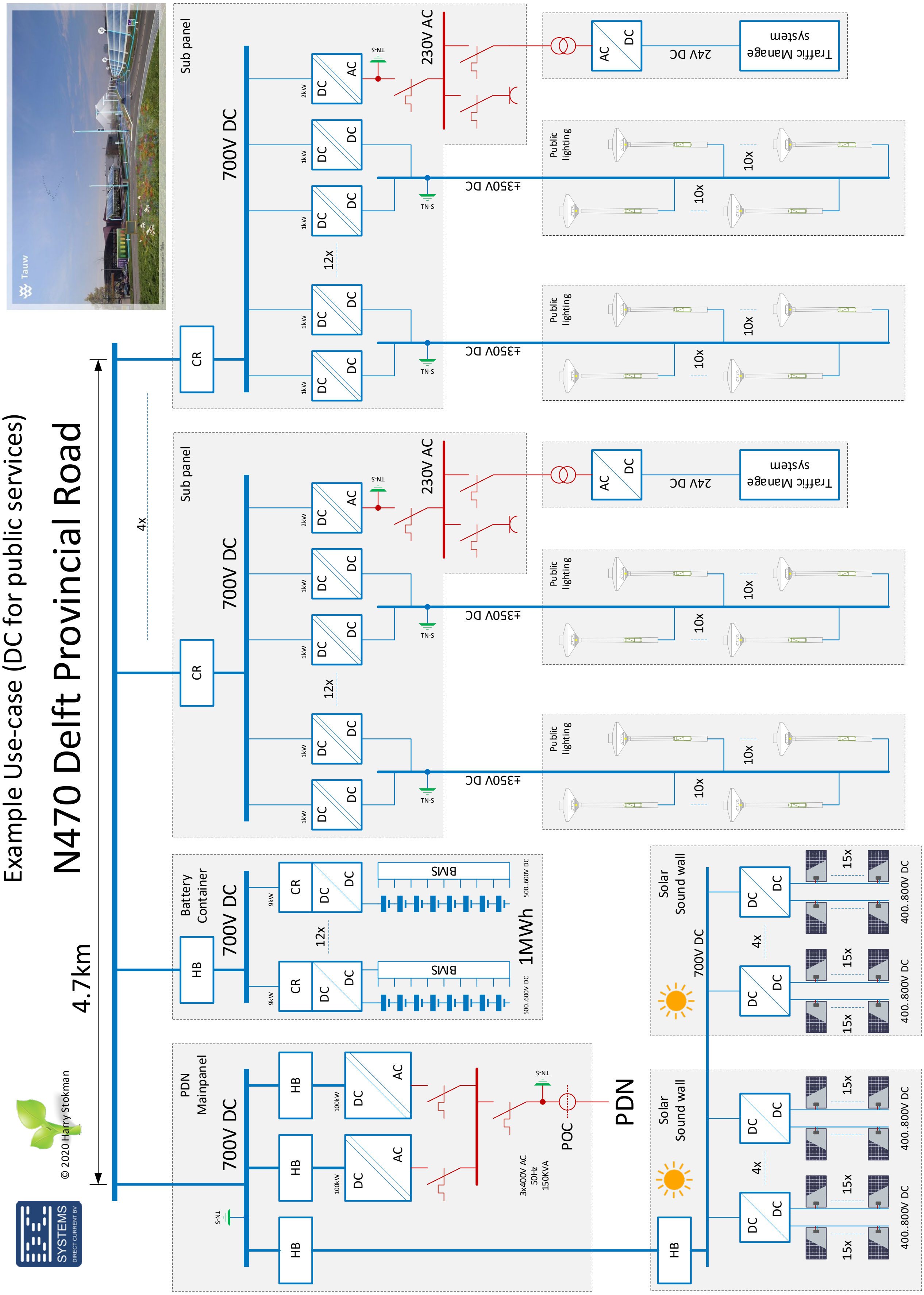
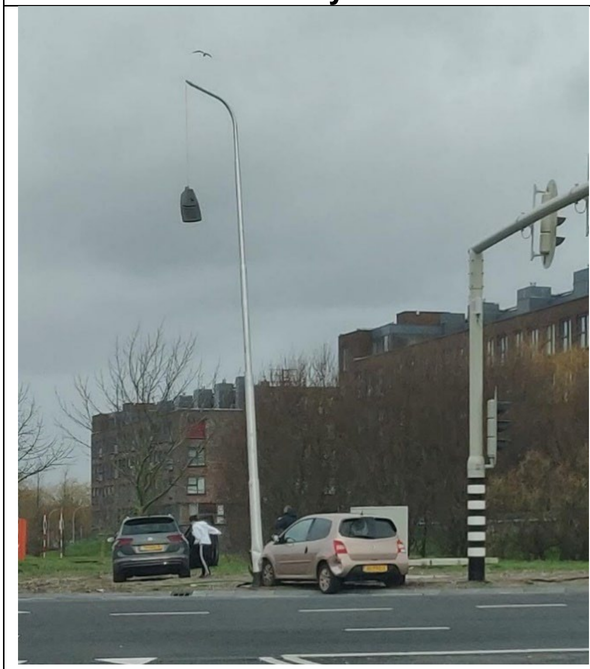


Figure: Single-line diagram of N40 site system.

Distributed batteries system

Outdoor substation



An illustration of why RCDs and protection are necessary. A minor accident occurred during testing when one of the cars collided with the project's light pole. In this particular picture, the biggest risk was the heavy armature just hanging on the wires and heavily waving in the storm at that time. The lady was just walking underneath. (safety comes first).

Outdoor substation for public lighting

Figure: The layout of the N470 project

In accordance with the Dutch standard for DC:

Agency	Number	Year	Name	Abstract	Short description	Voltage level
NPR	9090	2018	DC installations for low voltage	NPR 9090 is applicable to the design and installation of DC installations for low voltage (up to 1500 V DC) related to the scope of NEN 1010. Combined AC and DC installations are also included in the scope of this NPR as long as galvanic isolation is applied between the AC and DC parts.	This standard serves as the legal foundation for installation requirements, as the law refers to the wiring standards. As a result, this was an important standard to have when constructing DC installations for N470 project.	350-1500 V

https://www.nen.nl/en/npr-9090-2018-nl-250370

5 Benefits of Current OS Microgrid

Please refer to the dedicated white paper to have a complete understanding of Current OS Protocol based microgrid benefits. In the following paragraph, we will mainly highlight the benefits in this particular installation.

In this N470 project where the main bus is 4,7 km long. The Current OS Protocol system approach combining **DC and Solid State** technologies solves major issues.

One of the intrinsic benefits of DC distribution compared to AC distribution over such a large application is the absence of capacitive losses on the lines. DC allows RCD to detect 80mA (80mA DC RCD has an equivalent level of protection as 30mA AC RCD) earth leakage current faults on these long lines. This increases a lot people safety.

DC short circuit current are difficult to break with traditional electromechanical technology. Especially in this N470 project where the main bus is 4,7 km long. With traditional electromechanical technology a fault on such a bus would lead to the fast discharge of all capacitors in the sources and loads, creating a very high current and inductance of the cables would store energy in the milliseconds before fuses or electromechanical breakers start to operate. This would be sufficient to create a very high energy arc that most devices are not able to break and dissipate energy. It would also create a lot of extremely hot gas exhausts. In addition, cables and connectors would have to be dimensioned to withstand such a high fault current.

Solid state protection devices are generalized in this N470 application. The main bus is a DC Zone 3 bus. A fault is cleared within microseconds. So fast that capacitors have no time to push a very high current and cables inductance has no time to store energy. DC protection is much easier and faster.

Thanks to this ultrafast tripping, the cables and connections can be downsized at the nominal current value and not at the fault current or peak value.

Cables are also powered from both ends resulting in another optimization of conductor material use.

Last but not least, this solid state based technology also allow an extreme simplification of the protection scheme. There is maximum 2 protection layers between sources and loads.

Solid state technology has native capability for metering, communication. This allow energy monitoring of the application.

In this microgrid application, thanks to Current OS Protocol, the system is very simple.

There is no need for a complex and expensive automation and communication system on top of electrical distribution system. In an AC microgrid, this would be a critical point and could be exposed to cyber-attacks.

Thanks to Current OS Protocol, the voltage is the main information about power availability in the installation. All circuit devices can measure it and react accordingly. This makes extremely simple the microgrid stability management. And intrinsically cybersafe.

For the same reason, upgrades of this Current OS Protocol based microgrid are also drastically simplified by simple addition of a new device and circuit with appropriate priority settings.

Current OS Protocol adjusts permanently the demand to the power available. As a result, the power use from the public grid has been extremely limited. Power is coming from the public network only during battery system maintenance.

By parametrizing of the Active Front Ends in day- and night scenario’s, the installation is optimized for as low as possible losses. During the day the combination of PV and battery charging is optimized by the droop-curve, during night the battery to load voltage loss is optimized by a different droop-curve.

The full DC installation is able to run in island mode and it is even possible to blackstart the DC installation without the public AC grid power available.

During shiny summer days, this application also exports energy to the public grid thanks to its bidirectional connection to the AC network.

Current OS Protocol based solution helped to reduce the investment needed on the grid, as this application is almost autonomous in electrical power.