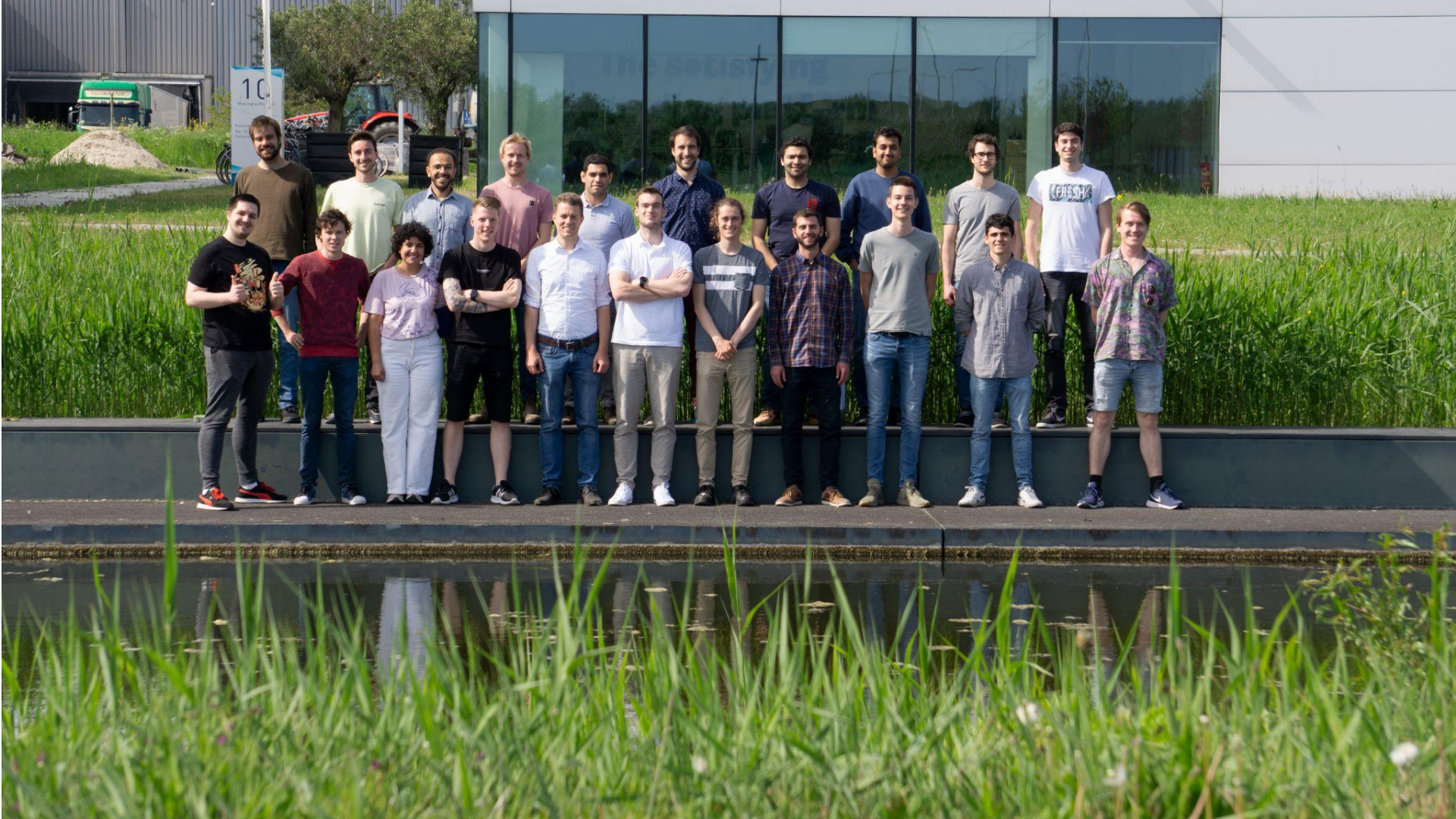
Second Life Battery Storage in DC Microgrids

Dr. Laurens Mackay
DC Opportunities
03/10/2023 Delft

DCpportunities

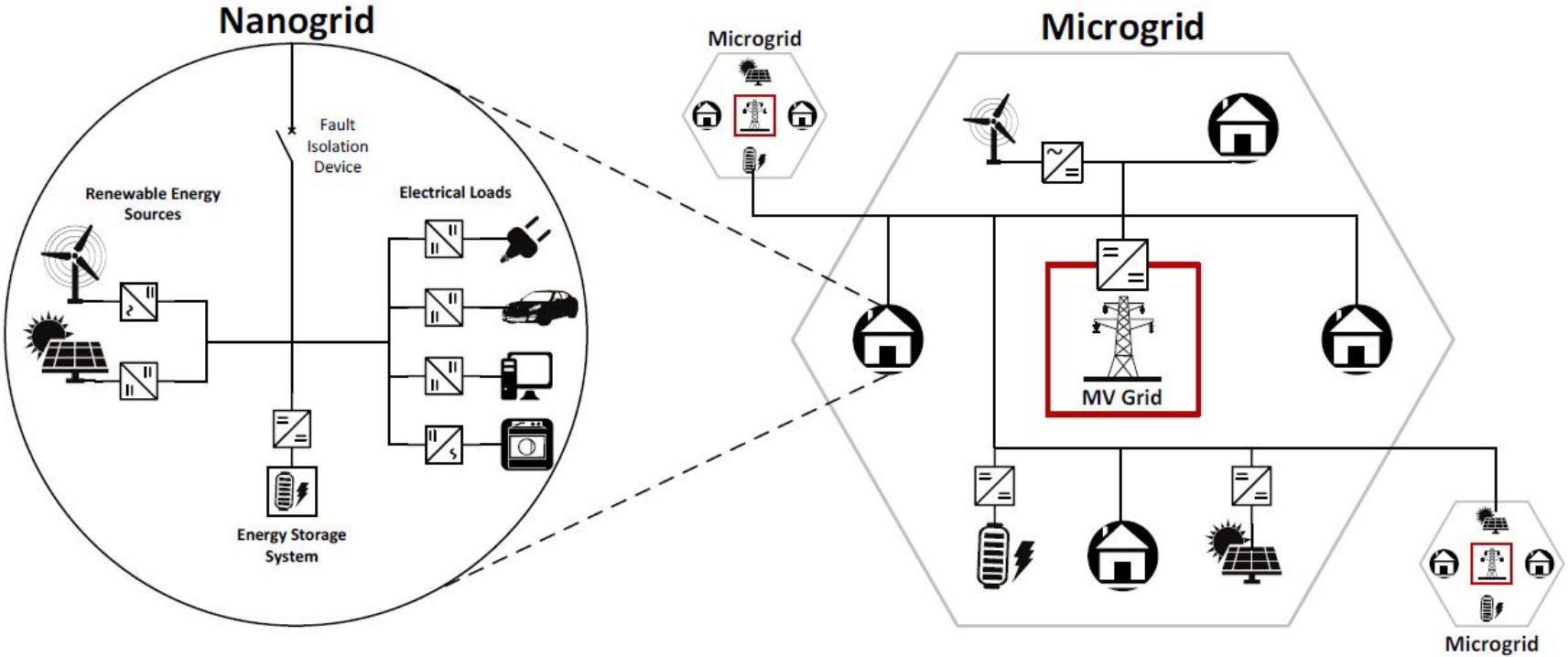


Future Power System

- Centralized Generation
- Distributed Energy Resources
- Nano- and Microgrids
- Off-Grid Systems

- Not only implement DC
- But also prepare for the future power system

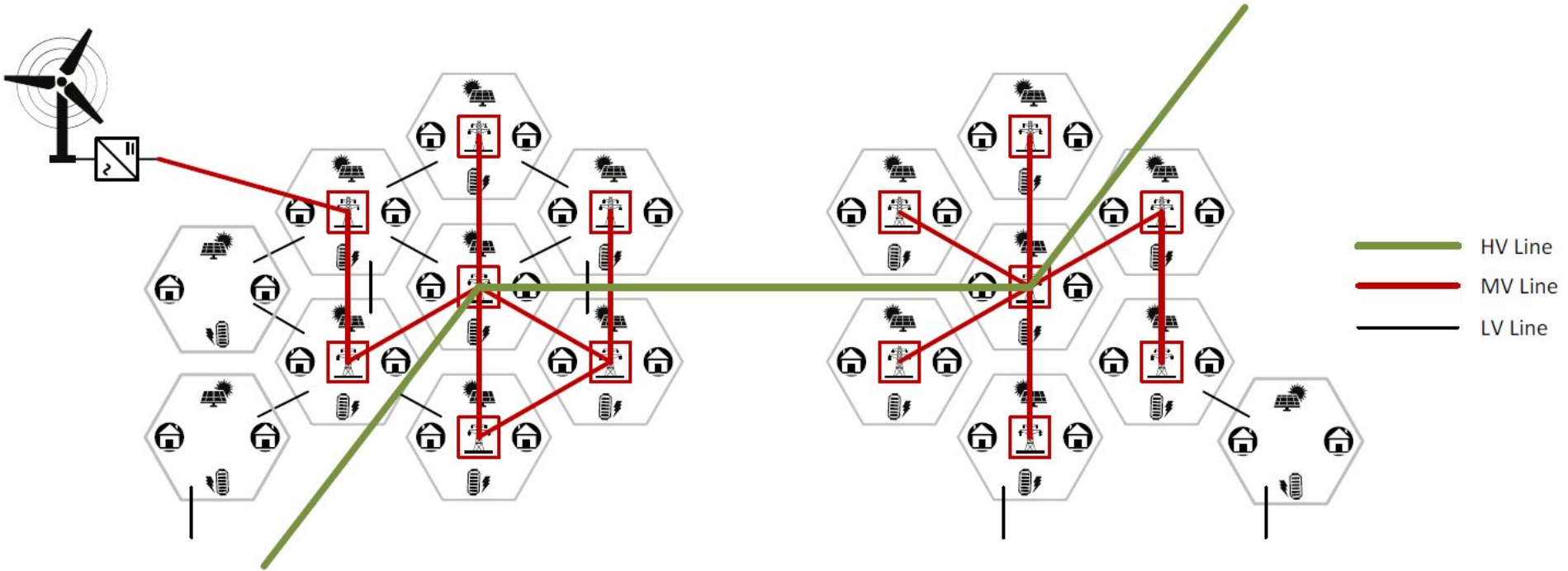
No Converter at Nanogrid's Interface



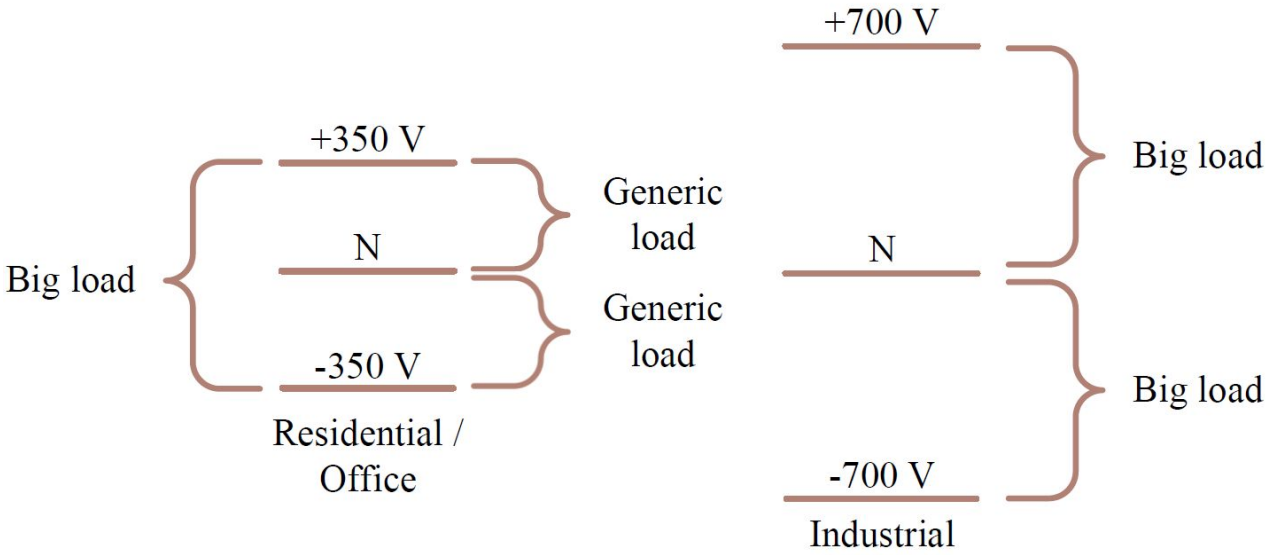
DCpportunities

L. Mackay, N. H. van der Blij, L. Ramirez-Elizondo, and P. Bauer, "Toward the Universal DC Distribution System," Electr. Power Components Syst., vol. 45, no. 10, pp. 1032–1042, 2017.

Meshed DC Distribution Grid



Modular Voltage Bipolar Levels



Second Life Battery Storage

- Electric Vehicles
- End of Life
  - Battery or Vehicle?
- Second Use
  - Lower performance requirement
- When and how?

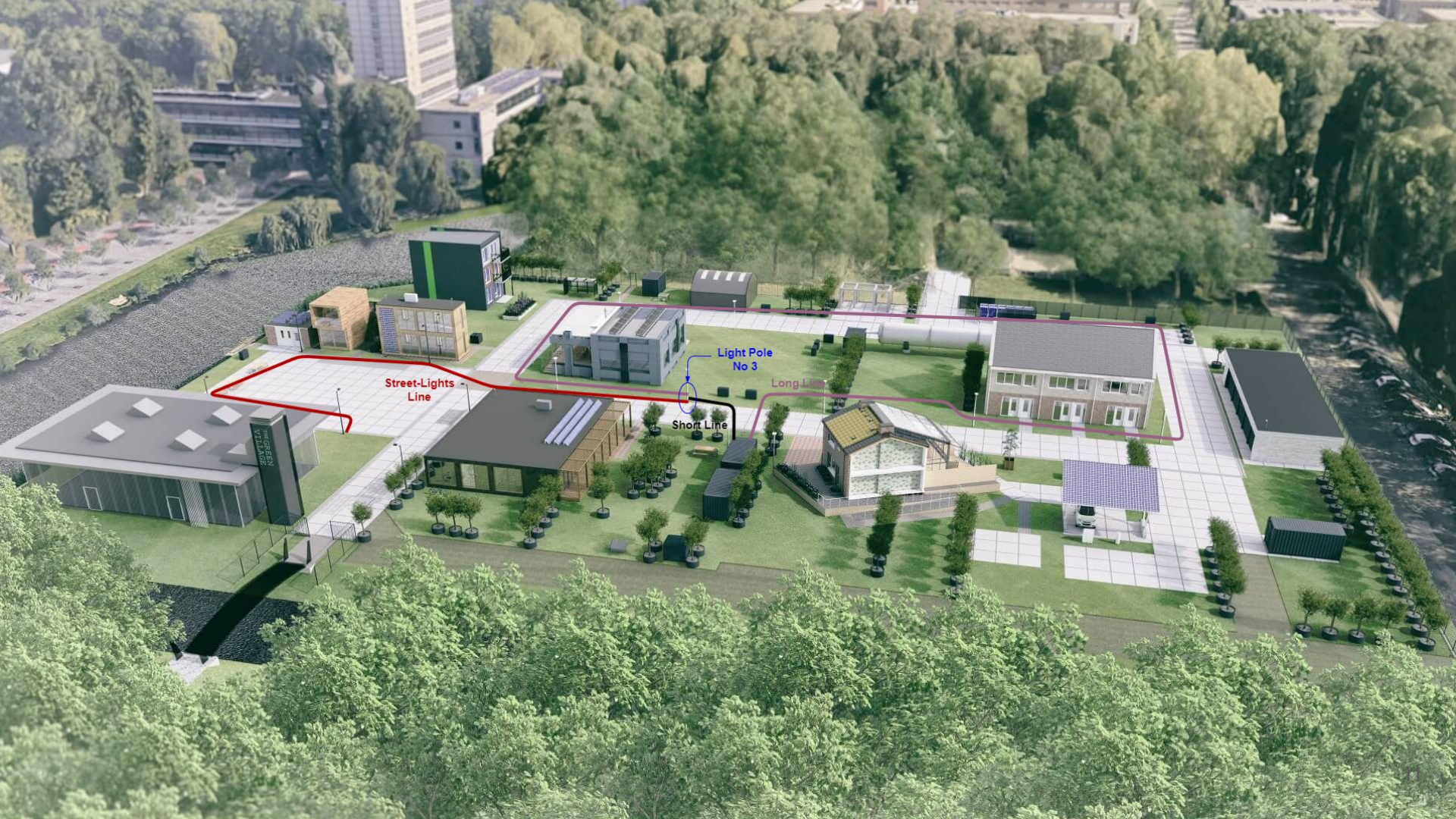
- Energy Storage
- Demand Response
- Flexibility
- V2G Bidirectional EV Charging
- Home Battery?

Battery Management System

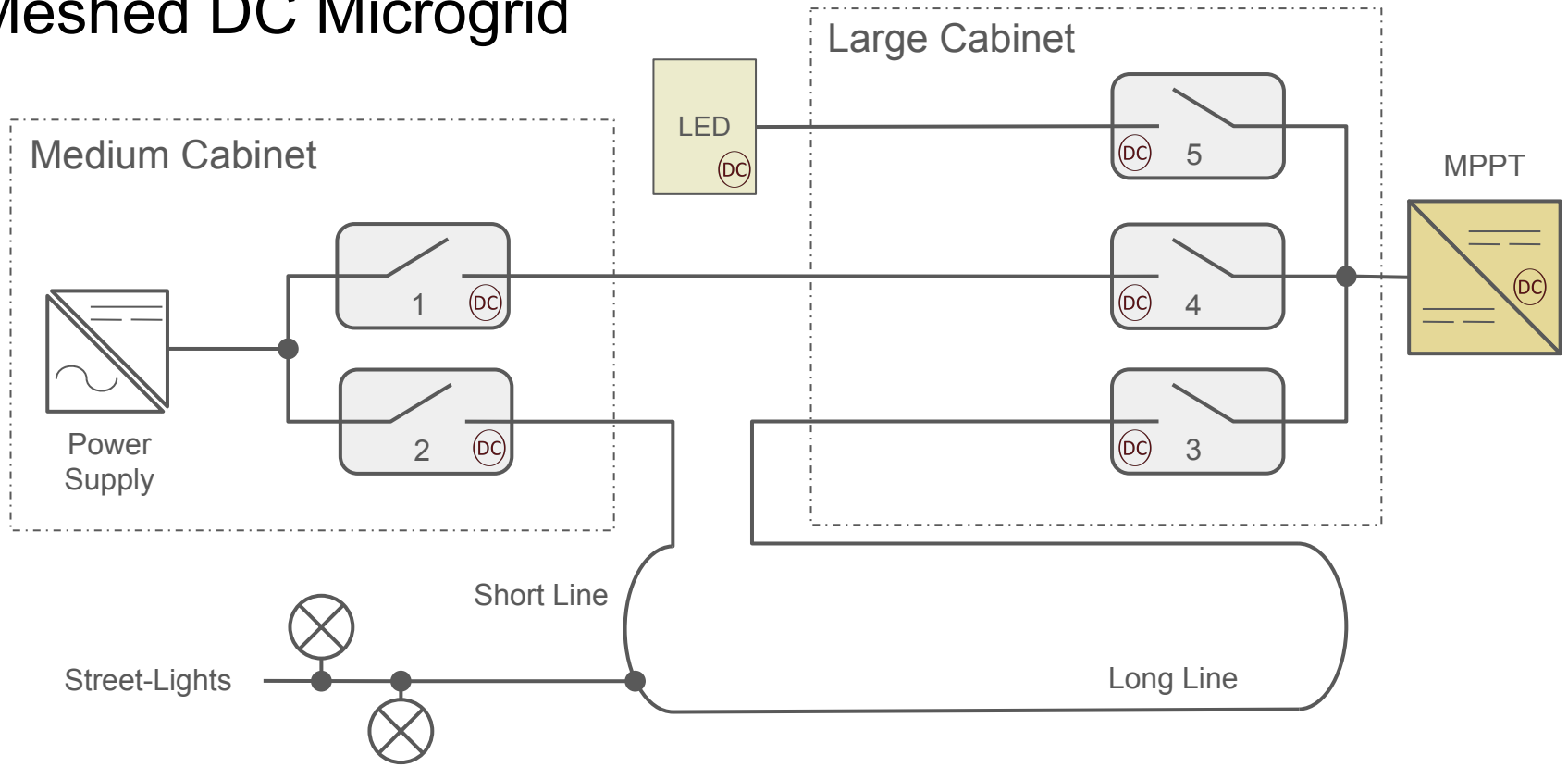
- Even more relevant than in first life
- Prediction End of Life
- Modularity
- Fault Tolerance

DCpportunities


Cell Voltages
3.3035
3.303
3.3025
3.302
3.3015
3.301
3.3005
3.3
10:30
10:35
10:40
10:45
10:50
10:55
11:00
11:05
11:10
11:15
11:20
11:25
11:30
11:35
11:40
11:45
11:50
11:55
12:00
Bat_Storage_B: Cell_Voltage 0 V1
Bat_Storage_B: Cell_Voltage 1 V1
Bat_Storage_B: Cell_Voltage 2 V1
Bat_Storage_B: Cell_Voltage 3 V1
Bat_Storage_B: Cell_Voltage 4 V1
Bat_Storage_B: Cell_Voltage 5 V1
Bat_Storage_B: Cell_Voltage 6 V1
Bat_Storage_B: Cell_Voltage 7 V1
Bat_Storage_B: Cell_Voltage 8 V1
Bat_Storage_B: Cell_Voltage 9 V1
Bat_Storage_B: Cell_Voltage a V1
Bat_Storage_B: Cell_Voltage b V1
Bat_Storage_B: Cell_Voltage 0 V2
Bat_Storage_B: Cell_Voltage 1 V2
Bat_Storage_B: Cell_Voltage 2 V2
Bat_Storage_B: Cell_Voltage 3 V2
Bat_Storage_B: Cell_Voltage 4 V2
Bat_Storage_B: Cell_Voltage 5 V2
Bat_Storage_B: Cell_Voltage 6 V2
Bat_Storage_B: Cell_Voltage 7 V2
Bat_Storage_B: Cell_Voltage 8 V2
Bat_Storage_B: Cell_Voltage 9 V2
Bat_Storage_B: Cell_Voltage a V2
Bat_Storage_B: Cell_Voltage b V2
Bat_Storage_B: Cell_Voltage 0 V3
Bat_Storage_B: Cell_Voltage 1 V3
Bat_Storage_B: Cell_Voltage 2 V3
Bat_Storage_B: Cell_Voltage 3 V3
Bat_Storage_B: Cell_Voltage 4 V3
Bat_Storage_B: Cell_Voltage 5 V3
Bat_Storage_B: Cell_Voltage 6 V3
Bat_Storage_B: Cell_Voltage 7 V3
Bat_Storage_B: Cell_Voltage 8 V3
Bat_Storage_B: Cell_Voltage 9 V3
Bat_Storage_B: Cell_Voltage a V3
Bat_Storage_B: Cell_Voltage b V3
Bat_Storage_B: Cell_Voltage 0 V4
Bat_Storage_B: Cell_Voltage 1 V4
Bat_Storage_B: Cell_Voltage 2 V4
Bat_Storage_B: Cell_Voltage 3 V4
Bat_Storage_B: Cell_Voltage 4 V4
Bat_Storage_B: Cell_Voltage 5 V4
Bat_Storage_B: Cell_Voltage 6 V4
Bat_Storage_B: Cell_Voltage 7 V4
Bat_Storage_B: Cell_Voltage 8 V4
Bat_Storage_B: Cell_Voltage 9 V4
Bat_Storage_B: Cell_Voltage a V4
Bat_Storage_B: Cell_Voltage b V4
Bat_Storage_B: Cell_Voltage 0 V5
Bat_Storage_B: Cell_Voltage 1 V5
Bat_Storage_B: Cell_Voltage 2 V5
Bat_Storage_B: Cell_Voltage 3 V5
Bat_Storage_B: Cell_Voltage 4 V5
Bat_Storage_B: Cell_Voltage 5 V5


Light Pole
No 3
Street-Lights
Line
Long Line
Short Line

Meshed DC Microgrid

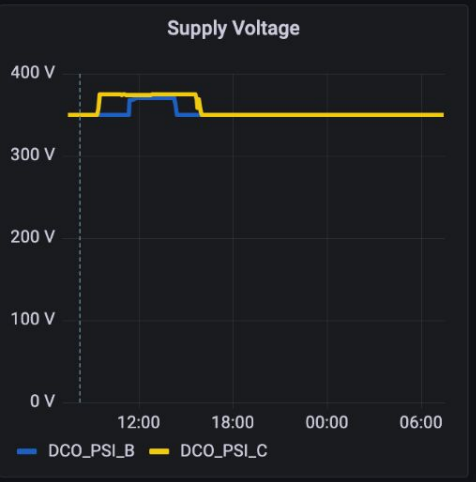


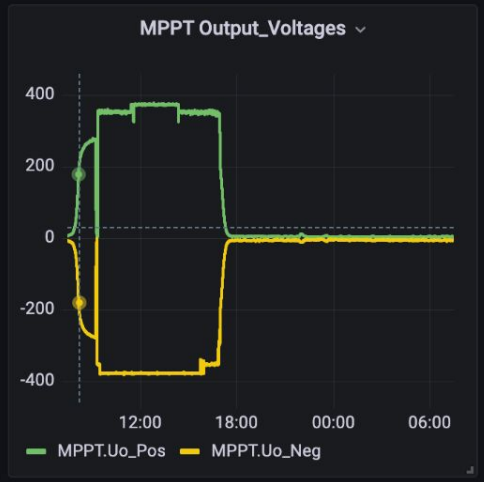
DCpportunities

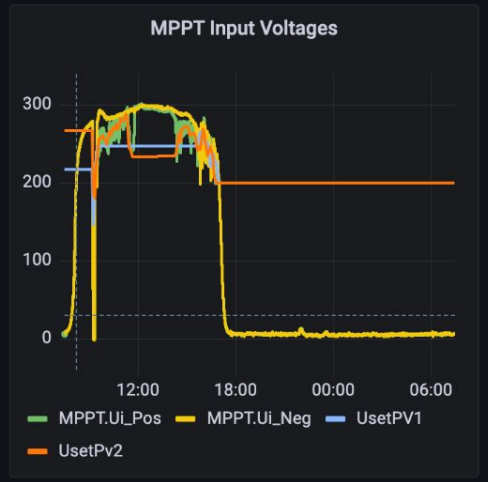
DC Second Life Battery Demo

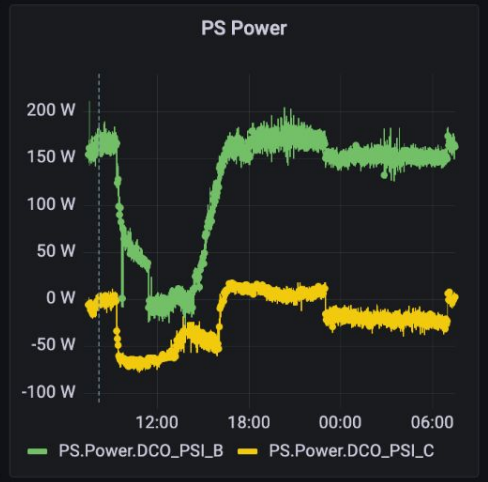
- DC Solid State Protection
- DC PV String Optimizer
- DC Balancing Converter
- DC/DC Storage Converter
- upVolt Second Life Battery

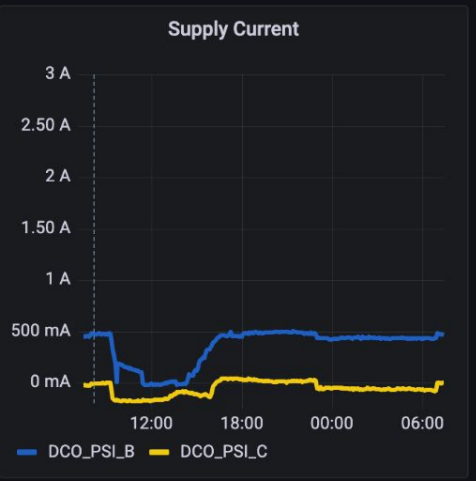
DCpportunities

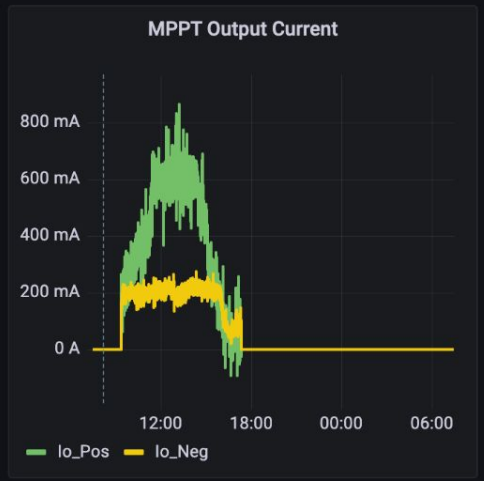

Supply Voltage
400 V
300 V
200 V
100 V
0 V
12:00
18:00
00:00
06:00
DCO_PSI_B
DCO_PSI_C

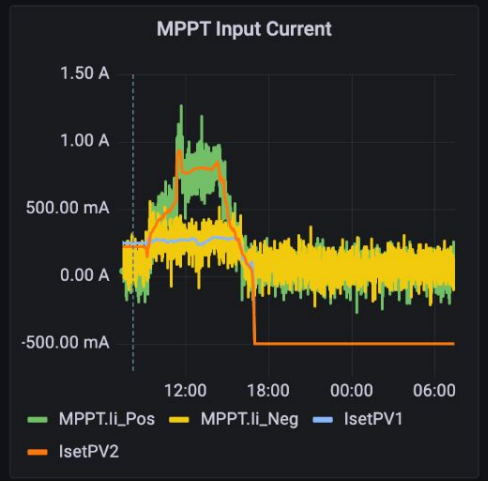

MPPT Output_Voltages
400
200
0
-200
-400
12:00
18:00
00:00
06:00
MPPT.Uo_Pos
MPPT.Uo_Neg

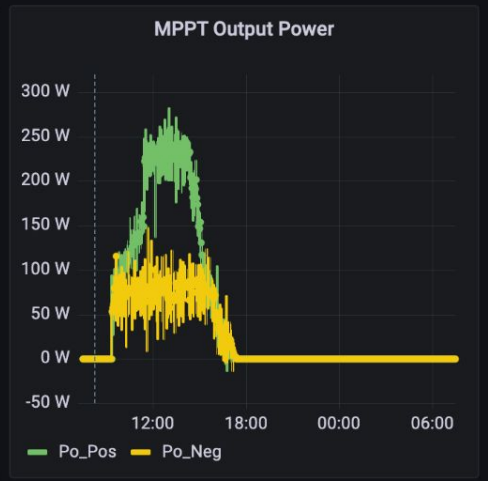

MPPT Input Voltages
300
200
100
0
12:00
18:00
00:00
06:00
MPPT.Ui_Pos
MPPT.Ui_Neg
UsetPV1
UsetPv2


PS Power
200 W
150 W
100 W
50 W
0 W
-50 W
-100 W
12:00
18:00
00:00
06:00
PS.Power.DCO_PSI_B
PS.Power.DCO_PSI_C


Supply Current
3 A
2.50 A
2 A
1.50 A
1 A
500 mA
0 mA
12:00
18:00
00:00
06:00
DCO_PSI_B
DCO_PSI_C


MPPT Output Current
800 mA
600 mA
400 mA
200 mA
0 A
12:00
18:00
00:00
06:00
Io_Pos
Io_Neg


MPPT Input Current
1.50 A
1.00 A
500.00 mA
0.00 A
-500.00 mA
12:00
18:00
00:00
06:00
MPPT.Ii_Pos
MPPT.Ii_Neg
IsetPV1
IsetPV2


MPPT Output Power
300 W
250 W
200 W
150 W
100 W
50 W
0 W
-50 W
12:00
18:00
00:00
06:00
Po_Pos
Po_Neg

Pilot Nieuw Reijerwaard

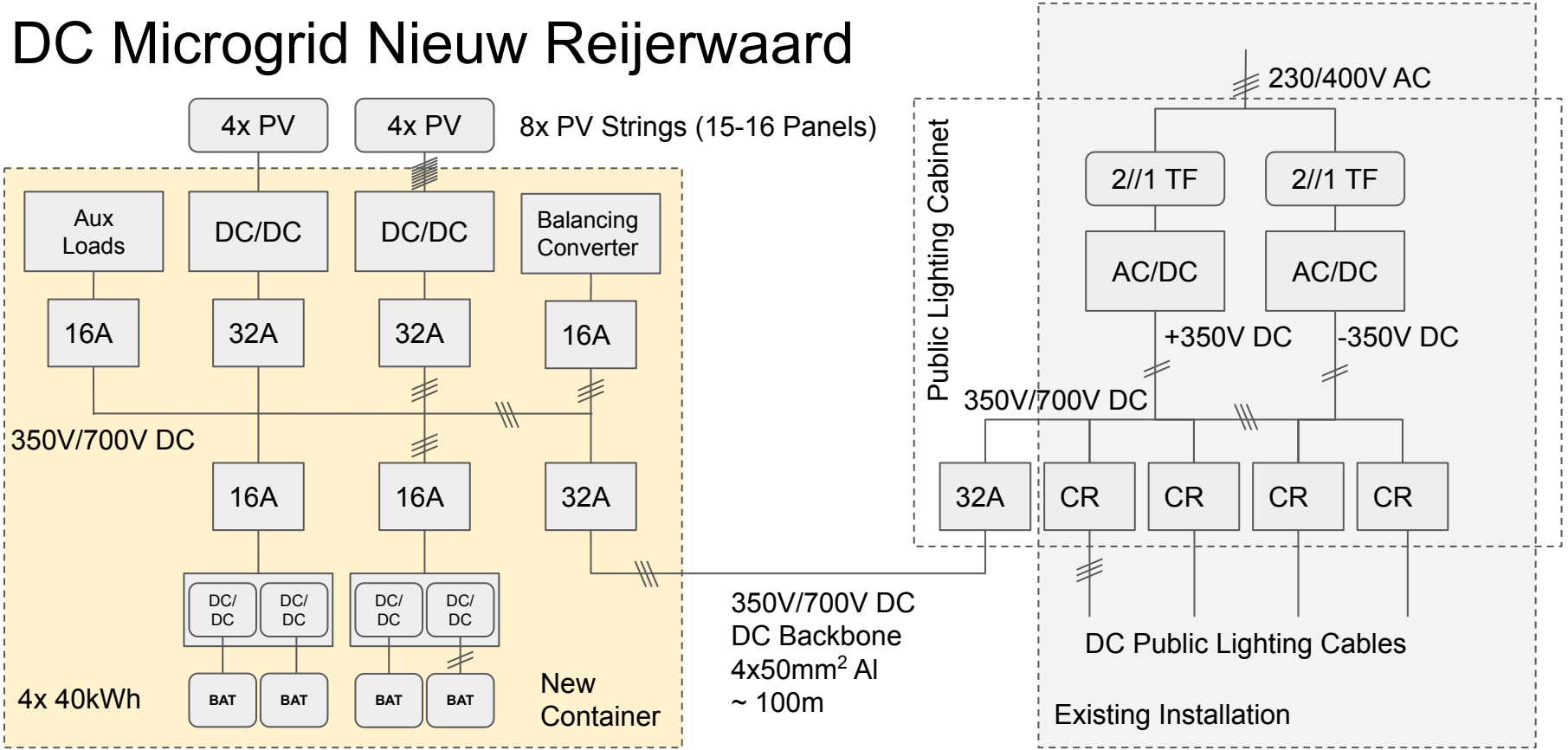
Existing:

- 10-15kW LED light
- 2x 10kW AC/DC
- ~100m 4x50mm2 Al backbone cable
- 40 kW PV on roof (not connected)

To be extended with:

- DC/DC PV MPPT Converter
- >120 kWh Storage
- Balancing Converter 350/700V
- DC Solid State Protection

DC Microgrid Nieuw Reijerwaard



DCpportunities

DC Microgrid in a Container

4x 40kWh Second Life Batteries

2x Battery Storage Converters

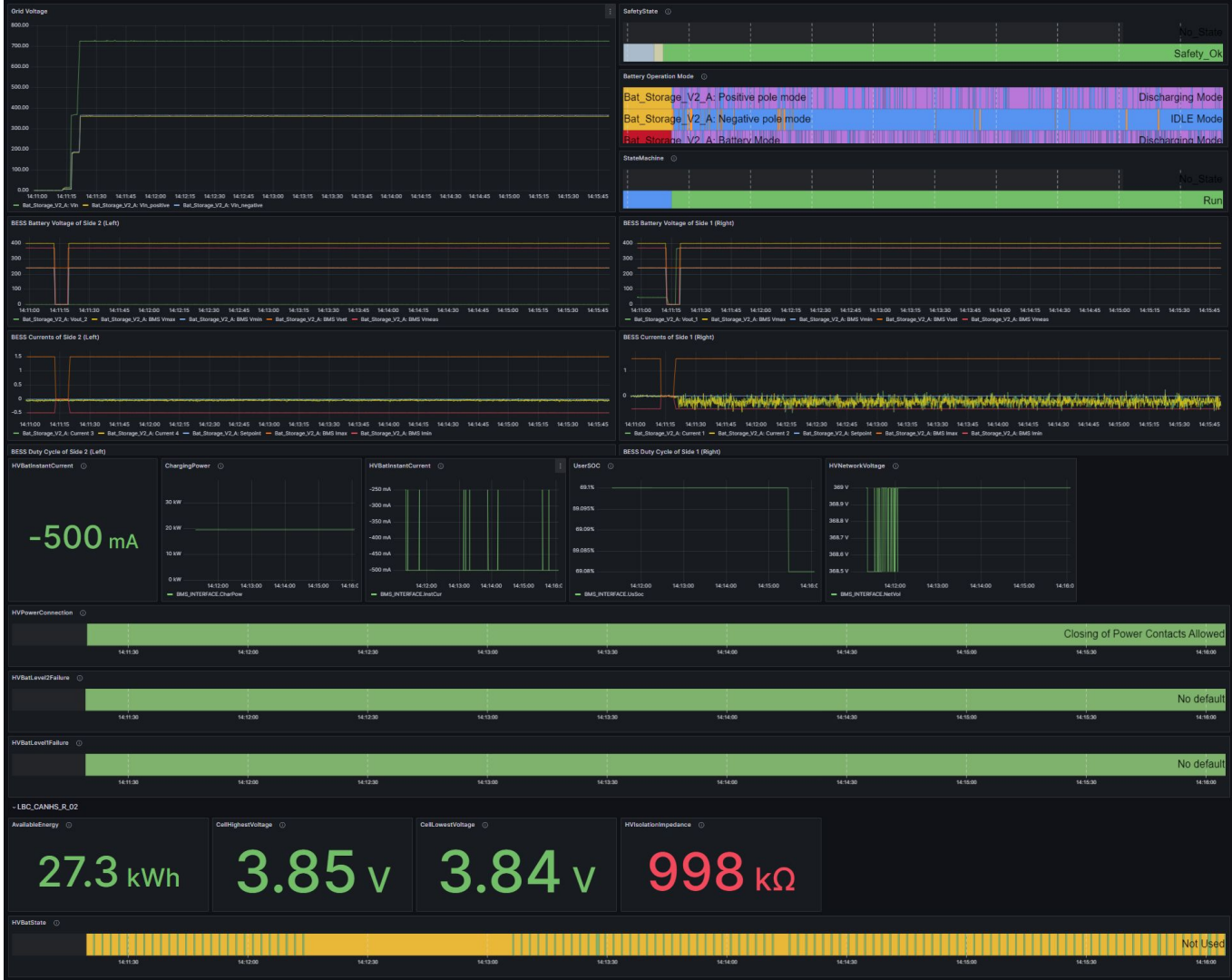
1x Balancing Converter

2x 22kW DC PV String Optimizer

DCpportunities


~500 mA
27.3 kWh
3.85 V
3.84 V
1000 kΩ
18 °C
19 °C
99 %
100 W


BESS 4



DCpportunities

2 x 5kW DC/DC V2G EV Charger

DCpportunities

Questions?

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