Challenges and Solutions in Modern DC Grids

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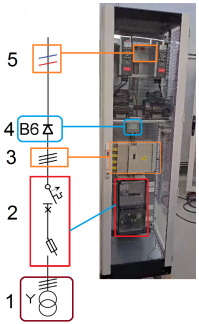
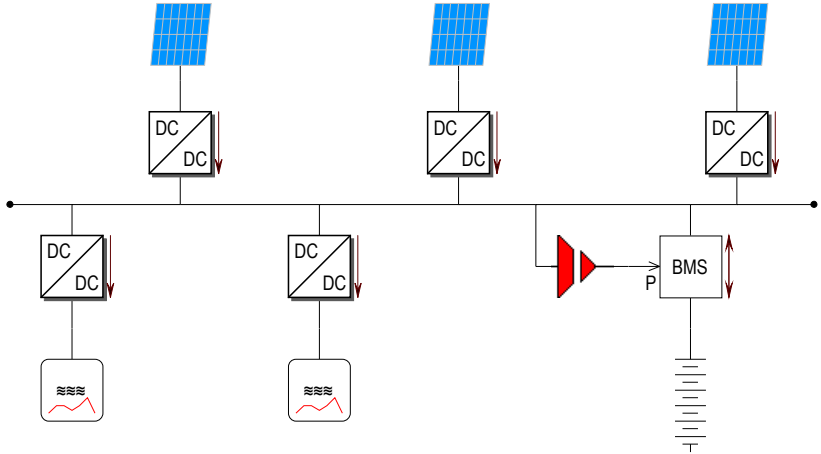


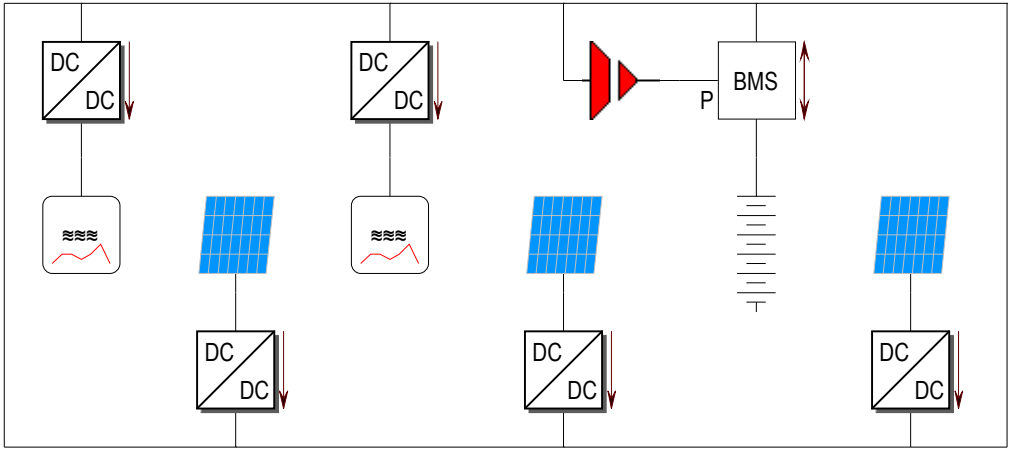
Part 1: Architecture and De nitions

Grid structure



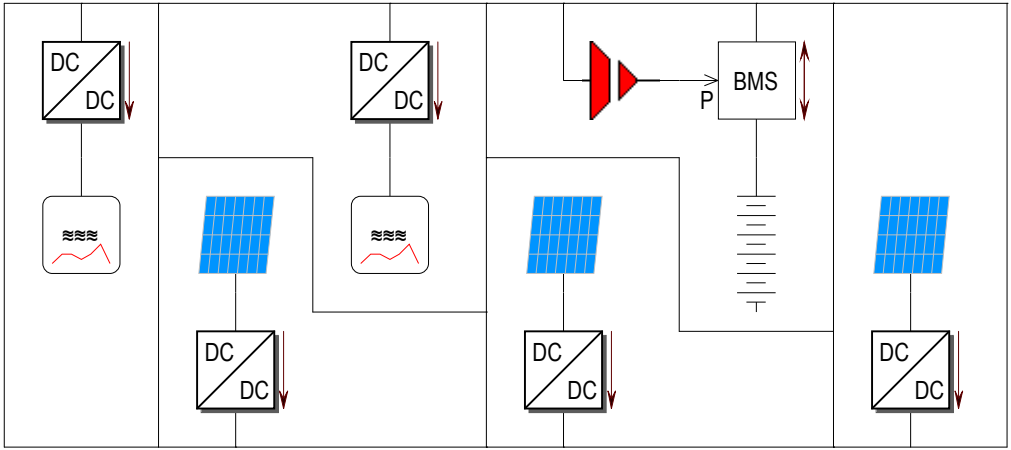
DC grid architecture, Radial grid.

Grid structure

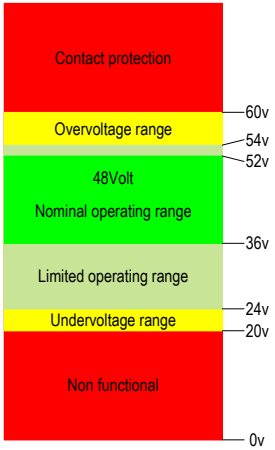


DC grid architecture, Ring grid.

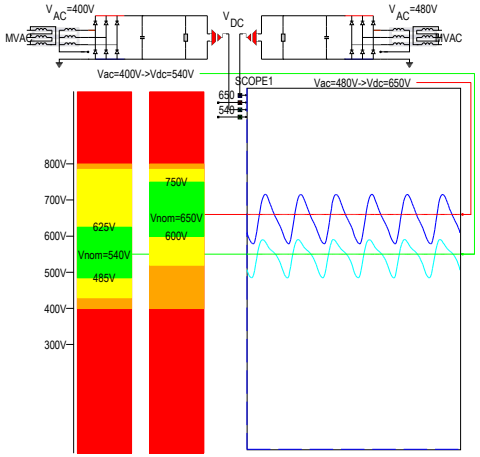
Grid structure



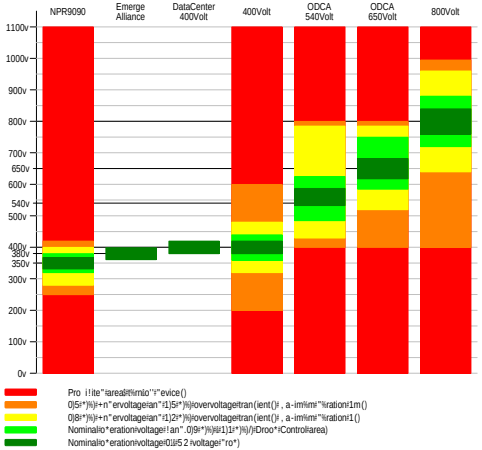
DC grid architecture, Meshed grid.



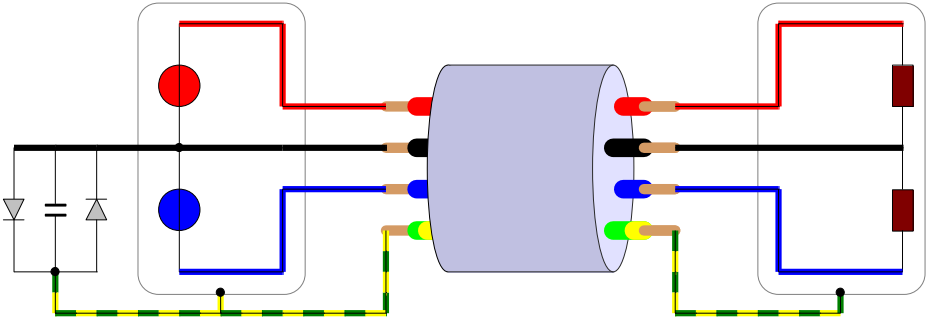
Normalization 48v automotive.



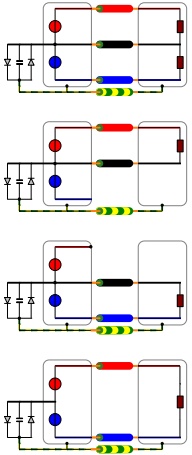
Normalization of two voltage levels by ODCA, where in a Caspoc simulation, the rectified three-phase voltage, $V^1_{AC_{RMS}} = 400V$ and $V^2_{AC_{RMS}} = 480V$ falls into the nominal operation region of $V^1_{Nom} = 540V$ and $V^2_{Nom} = 650V$



Normalization of voltage levels



Coloring conventions in a bipolar grid, plus-red, negative-blue, neutral-black, ground protection-yellow/green. The neutral is connected to ground via diodes.



Color conventions in unipolar and bipolar DC grids, from top to bottom: Bipolar, Unipolar-Positive, Unipolar-Negative, Unipolar.

Voltage	Polarity	Color
Positive	P	Red
Neutral	N	Black
Negative	M	Blue

Table: Polarity and color for Bipolar and Unipolar grids and cables.

Safety zones(left) in a DC grid and their applications(right).

Part 2: Control and Converters

Simulation in Caspoc, of a DC grid connected to a B6 recti er, feeding two variable speed drives. Brake energy from one drive, can be reused by another drive, via the DC grid.

Two DC grids, coupled via an Interlink. Each DC grid has a Grid Manager for interfacing prosumers like a battery, solar panel and a variable power load. Grid-A is connected to an grid via an AFE. Grid-B has local storage.

Droop regulation in an Active Front End, only a voltage above 540v can be regulated for a 400volt three-phase AC grid.

Cascaded voltage/current control for each type of DCDC converter. Thew cascaded droop control regulates the voltage level, but also dictates the maximum current, as regulated by current regulator. The protection on either side of the DCDC converter directly interacts wit

Using an extra isolated DCDC converter, a droop control voltage level can be created from
constant DC voltage provided by the AFE.

Droop characteristics for prosumers, From top to bottom: solar, battery, AC-grid and consumer.

Parameters of the droop characteristic centered at V_{nom} with limits P_{min} and P_{max}. A: Continuous characteristic with gain K. B: Discontinuous characteristic with centered blanking time around V_{nom}, with gains K_{min} and K_{max}.

Table: Bandwidth and reaction time, for each section in the control.

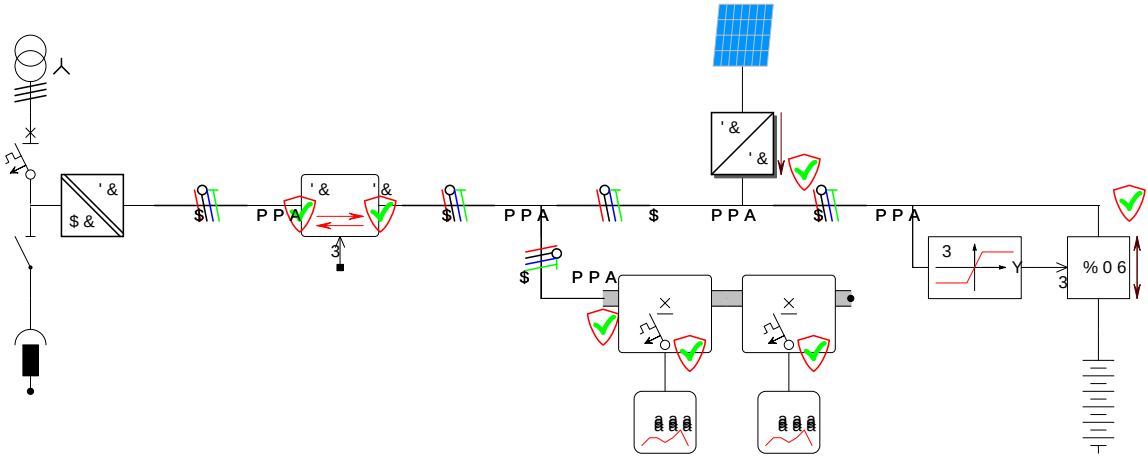
Control	BW [Hz]	t [s]
Current Mode	1MHz	< 1 s
Voltage Mode	1kHz	< 1ms
Droop Mode	1Hz	< 1s

DC distribution busbar with two controlled induction motor drives. From bottom to top:1)AC400V feeder cable, 2)AC over-current and earth leakage protection, 3)AC busbars[L1-L2-L3-N], 4)ODCA compatible B6 recti er, 5)ODCA compatible 540V DC grid

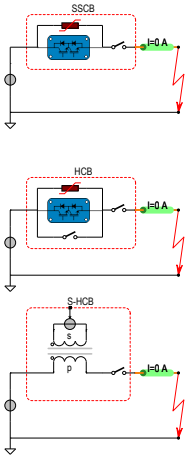
Part 3: Protection and Safety

Various types of mechanic, electronic, hybrid and current injected breakers.

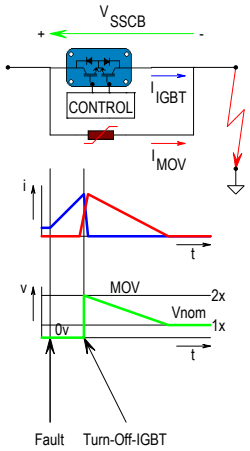
Electronic protection is included in the DCDC converters like the Interlink and Grid Manage
The Active Front End [AFE] has a mechanical breaker and fuse on the AC grid side.



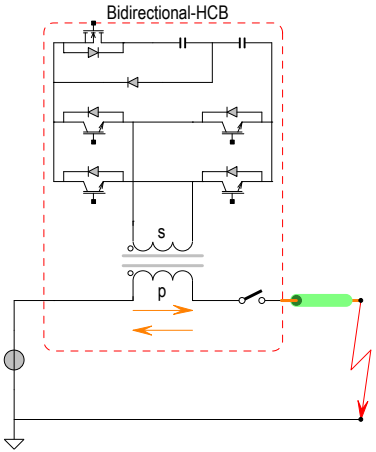
Electronic protection at both sides of the Interlink and at the entry of the Grid Manager. Each terminal connected to a prosumer has electronic protection. The "Shield" icon represents the combination of the electronic protection devices.



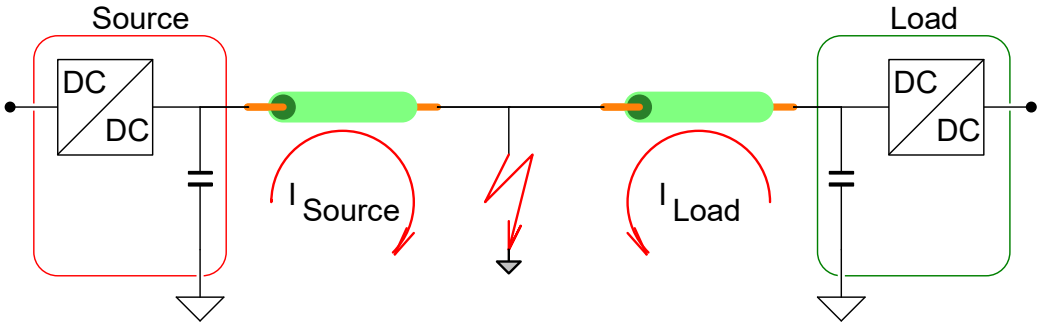
Short Circuit Current Breaker, from top to bottom: Solid State Circuit Breaker, Hybrid Circuit Breaker, Series Counter-voltage Breaker.



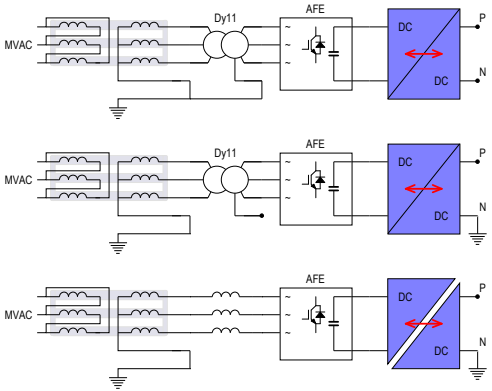
Wavefoms during turn-off in a SSCB. The voltage V_{SSCB} equals the voltage over the MOV, until the current returns to zero. After Turn-off of the SSCB, the voltage over the SCCB equals the nominal grid voltage, until the fault is cleared.



Bidirectional solid circuit breaker with counter current injection. Depending on the direction of the fault-current, the full bridge can make either a positive or negative counter-voltage, to cancel the voltage over the mechanical switch.



Short circuit current provided by the output capacitor of the source and input capacitor of the load.



Galvanic isolation between the AC and DC grid. From top to bottom: a)Isolation by the AC transformer, P and N are floating around the midpoint of the secondairy transformer winding. b)Isolation by the AC transformer, the negative terminal N is connected to ground. c)Isolation by the isolated DCDC converter, the negative terminal N is connected to ground.

During maintenance, the same procedure is perform as in AC grids:

- Shut down the system
- Lock the system
- Manual short circuit

Conclusion

- Architecture and Definitions
- Control and Converters
- Protection and Safety

Thank you!
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Multumesc!