LVDC Microgrid at Industrial Site

Essence and Challenges

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Background on BASF Antwerp, CDS, and myself

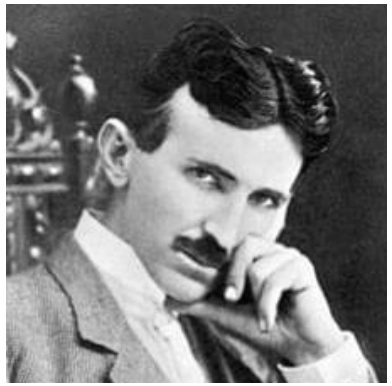
- BASF Antwerp is a large chemical site in the Antwerp Harbor:
  - area: 6km^2 (≈downtown Antwerp)
  - employees: 3277
  - revenue: ≈6 billion euro
  - power consumption: ≈400MW (3% of Belgium)
- Regulated electricity network: *Closed Distribution System*
  - Ensure *fair and equal access* for third parties on site
  - Following safety, *maximum availability at the correct price* is the second objective of CDS Operator
  - 150kV → 400V: 388 transformers, 200km cable, and 967 cubicles
- Tom Van Acker
  - M.Eng., M.Sc., and Ph.D. in electrical engineering from KU Leuven
  - Power system expert at BASF Antwerp, Department of Technology Expertise Power (ESP/IX)
  - Interests: optimization and uncertainty in a power system context, applied to availability, harmonics, optimal power flow and state estimation

Why consider LVDC microgrids at an industrial site?

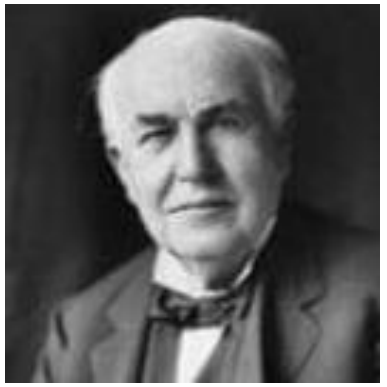
As part of *concluded* VlaIO project MultiDC (HBC.2019.0084)

Power system landscape is changing… even at an industrial site

Nikola Tesla



Thomas Edison



	alternating current	direct current
generation	large synchronous generation	distributed generation, incl. pv, battery…
load	direct-on-line motor	variable frequency drive (±30%)

goal: develop a *concept* to integrate ‘dc’ assets in *existing infrastructure*

PRIORITIES

1. safety
2. availability
3. service-to-grid
4. efficiency

AVOID CAPEX

1. minimal equipment
2. standard equipment

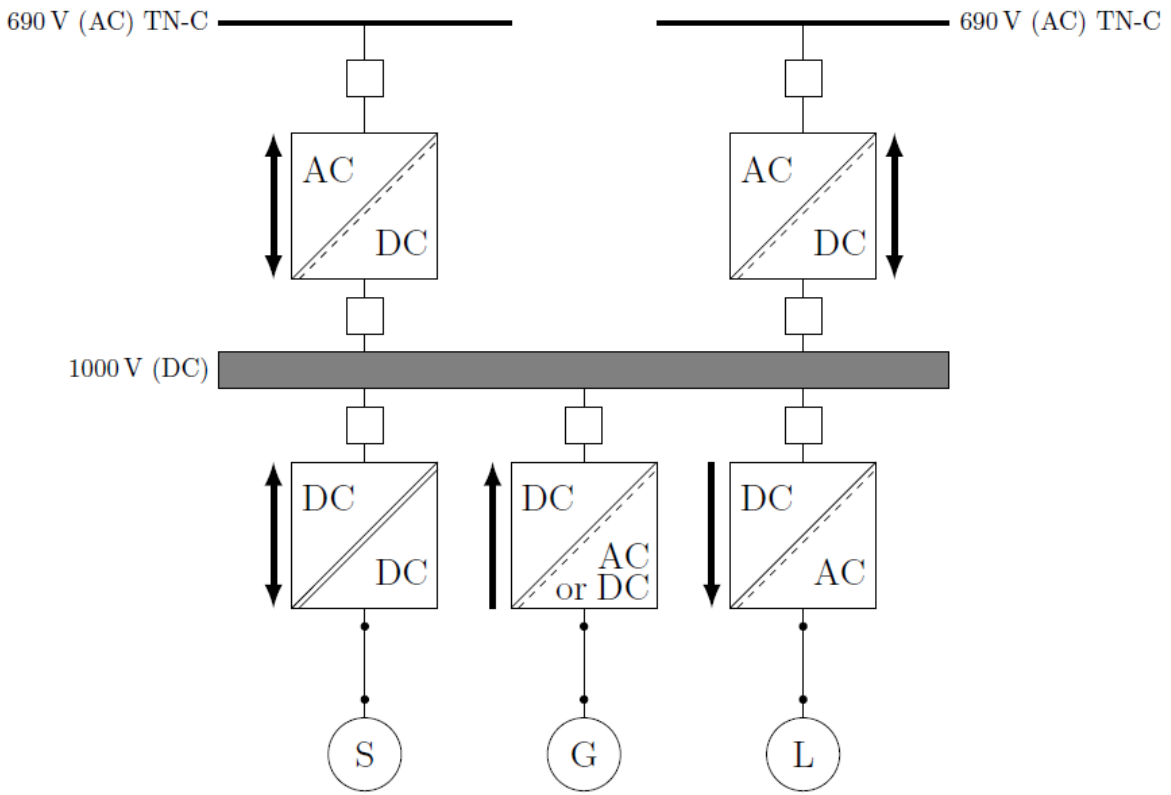
What should a LVDC microgrid look like?

As part of *concluded* VlaIO project MultiDC (HBC.2019.0084)

System description

DC-bus with possible connections to:

- ***At least* two** separate AC grids
  - Bi-directional front-end AC/DC converters (AFE)
- ***Multiple*** critical loads (L)
  - Motor-driven loads (pump, compressor, etc.)
  - Uni- or bi-directional DC/AC converters
- ***Multiple*** forms of storage (S)
  - Battery, Supercapacitors, etc.
  - Bi-directional DC/DC converter
- ***Multiple*** forms of generation (G)
  - PEM Fuel Cell, PV, Diesel-group, etc.
  - Uni-directional DC/DC or AC/DC converters



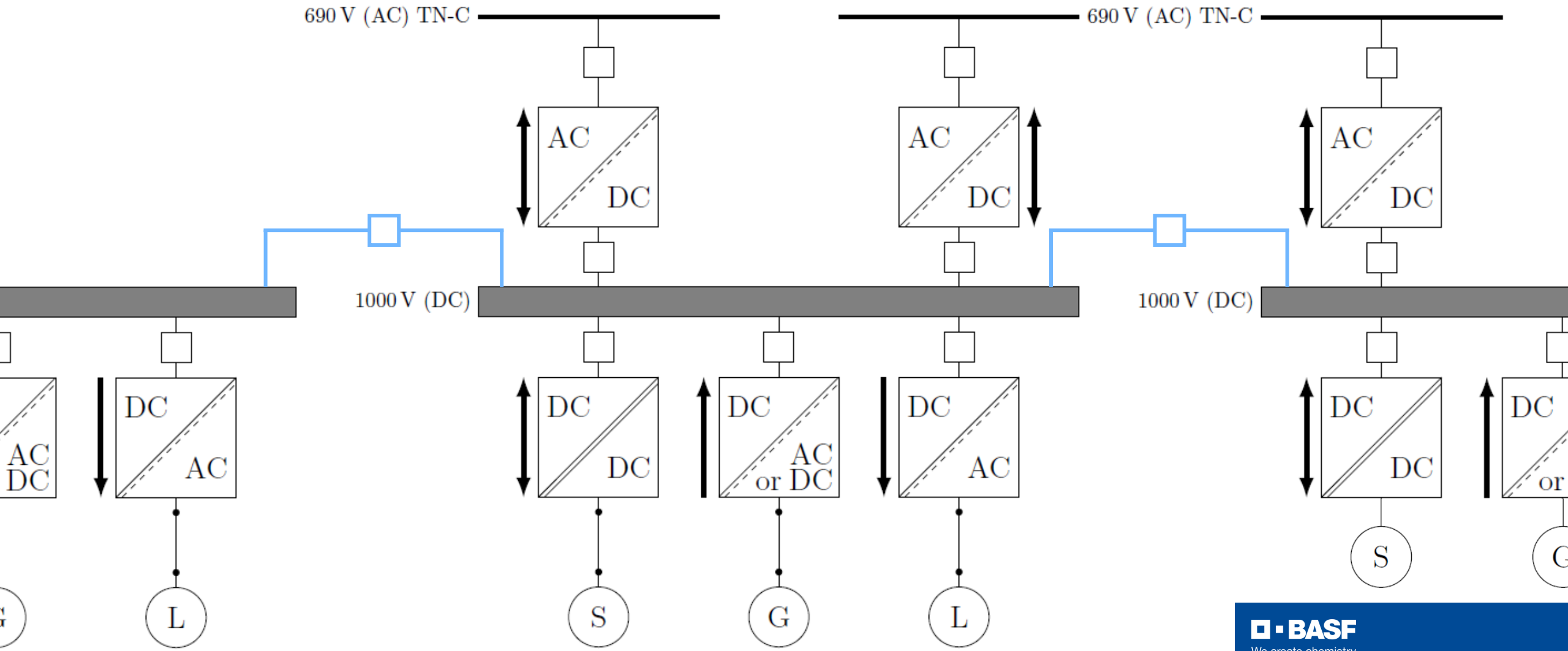
System description / First orders of magnitude

DC-bus → ~ 1000V DC **with possible connections to:**

- ***At least* two** separate AC grids → AC 690V TN-C, standard in industry
  - Bi-directional front-end AC/DC converters (AFE) → total 2MVA, each
- ***Multiple*** critical loads (L)
  - Motor-driven loads (pump, compressor, etc.)
  - Uni- or bi-directional DC/AC converters → up to 300kVA, each
- ***Multiple*** forms of storage (S)
  - Battery, Supercapacitors, etc.
  - Bi-directional DC/DC converter → 100kVA up to 1MVA
- ***Multiple*** forms of generation (G)
  - PEM Fuel Cell, PV, Diesel-group, etc.
  - Uni-directional DC/DC or AC/DC converters → 100kVA up to 1MVA

Note, these values are first estimates and subject to change.

System description / Future: Connecting multiple local LVDC grids



What is the issue? Just build it! Well…

As part of *ongoing* VlaIO ICON project LVDC, within Flux50 cluster

Let's take a step back… what was the goal again?

goal: develop a *concept* to integrate 'dc' assets in *existing infrastructure*

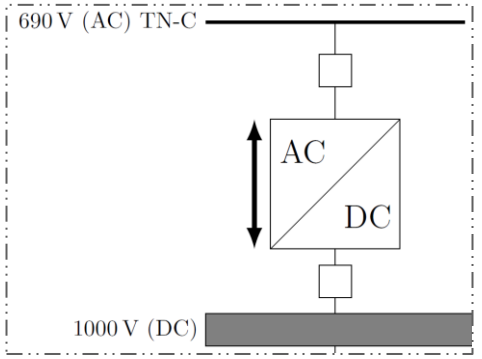
PRIORITIES

1. safety
2. availability
3. service-to-grid
4. efficiency

AVOID CAPEX

1. minimal equipment
2. standard equipment

- integrated in existing infra – connected to ac system with TN-C earthing system
- minimal equipment – no additional transformer provide galvanic isolation
- standard equipment – ac/dc converter, 2-level, non-galvanic isolated

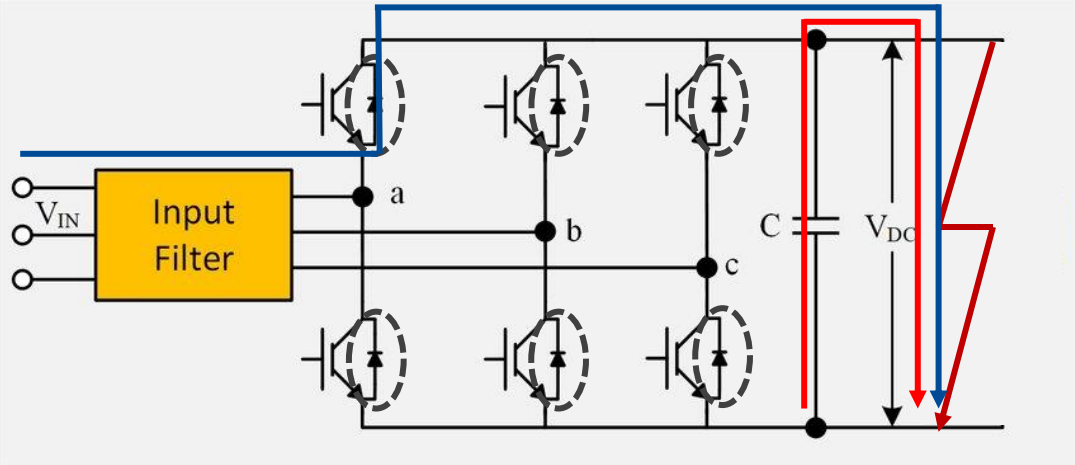


Consequence: *integrated earthing system between ac and dc systems*

impacts…

1. safety – different fault behavior
2. availability – selective protection

One minute introduction to dc short-circuit fault behavior of an ac/dc converter

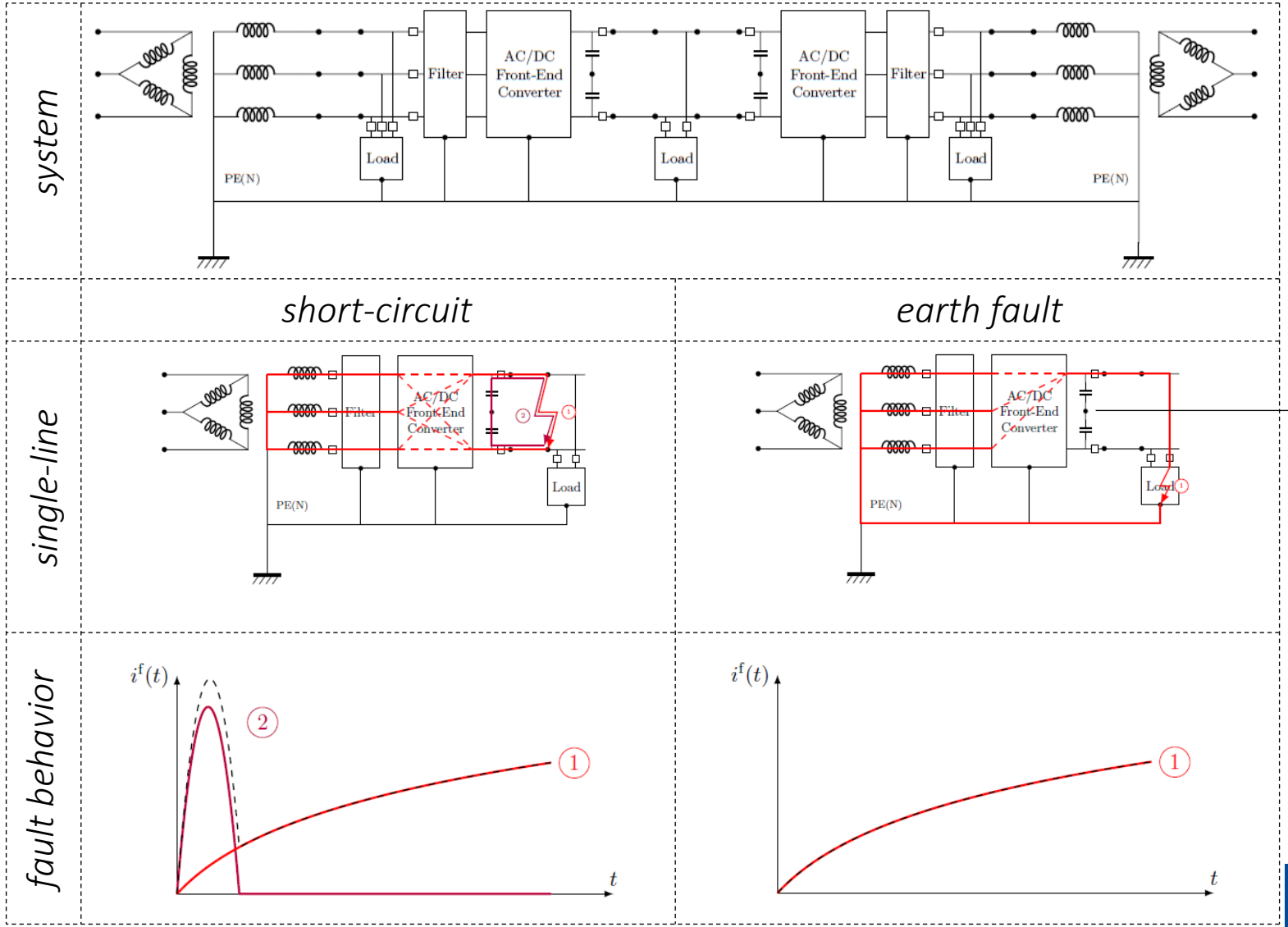


Stage one: discharge of capacitances (time cte: µs)

effect: - dc voltage reduces
- freewheeling diodes start conducting

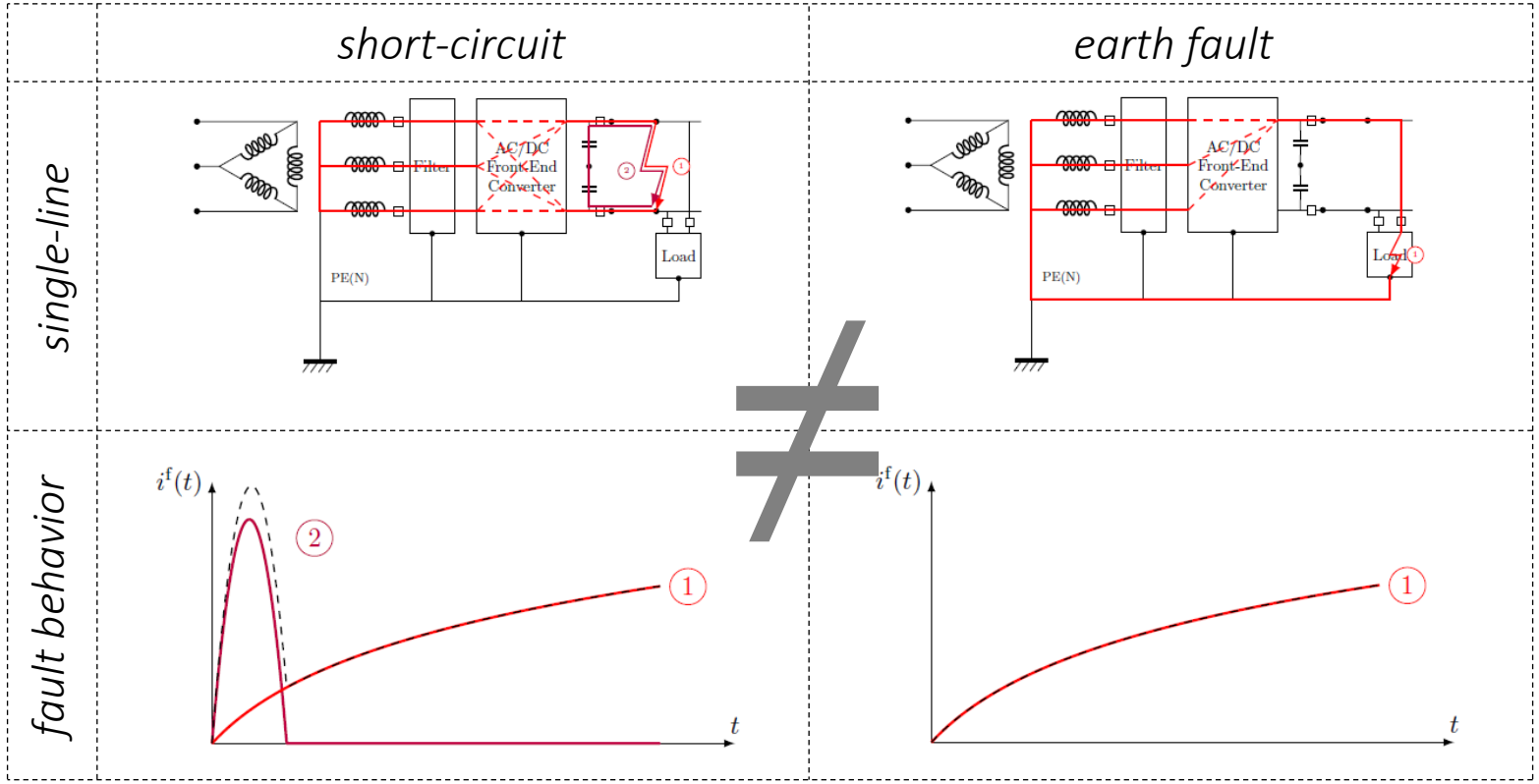
Stage two: ac grid feeds fault (time cte: ms)

What is the impact of removing galvanic isolation between ac and dc



Capacitance is not part of the earth fault path

What is the impact of removing galvanic isolation between ac and dc

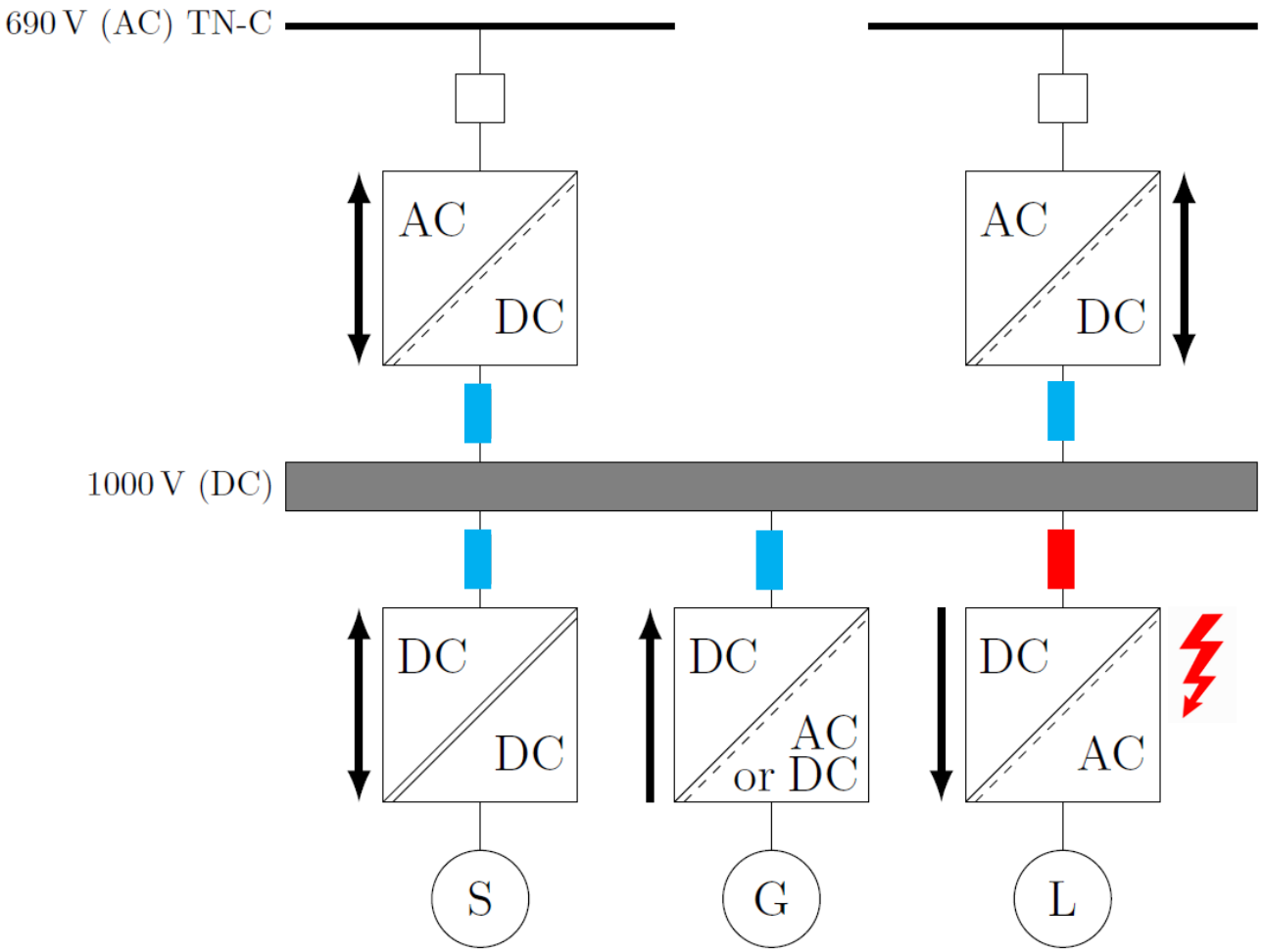


Major goal of the ICON LVDC project:

develop a protection strategy for non-galvanic isolated LVDC systems, such that:

- It is safe for both people and equipment;
- It is compliant with (Belgian) regulation; and
- It is selectively protected, to obtain ultra-high availability.

What is selective protection in an LVDC-grid – Illustration



A *fault on a branch* of the LVDC system is selectively cleared if it is cleared before other branches are disturbed, for example by:

- *protection of the non-faulted branches* acting,
- internal protection of the converters acting, or
- dc-bus voltage dropping below spec.

Goal:

- the LVDC system should continue with only losing the faulty branch, achieving ultra-high availability
- the protection of a non-faulted branch should only work if the protection of the faulted branch refuses service.

What protective devices can be used to enact the chosen protection strategy

	fuses	*solid-state circuit-breaker*
illustration		
proven technology	✓	?
protection method	I^2t	*I, dI/dt, etc.*
selective	?	✓
ntw dep. dimension	✓	✓
cost	*$*	*$$$*

Some more background on VlaIO ICON project LVDC, within Flux50 cluster

How is part of the consortium and what are their competences?

design, control and protection
of LVDC systems

DEP
DIRECT ENERGY PARTNERS

LVDC modeling
LVDC simulation
LVDC lab at EnergyVille

KU LEUVEN

BASF
We create chemistry

industrial power system
with ultra-high availability

ABB

supplier of solid-state circuit-breakers
for LVDC systems

If this seems interesting or relevant for your company, please contact prof. Michael Kleemann to join the industrial advisory board of the project, at michael.kleemann@kuleuven.be

BASF
We create chemistry

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We create chemistry