LVDC DISTRIBUTION SYSTEMS AS DRIVERS FOR RENEWABLE ENERGY INTEGRATION

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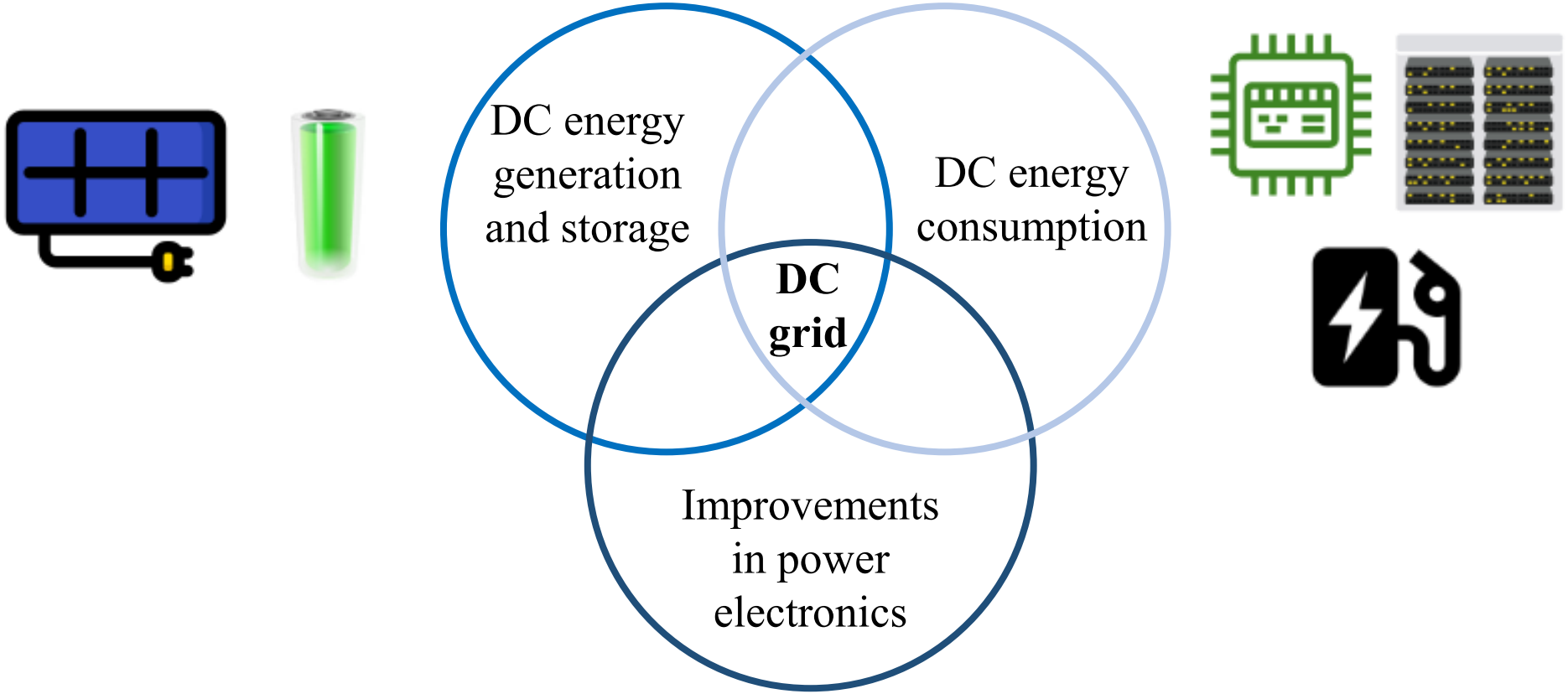
Summary

1. Introduction

- Rising visibility of LVDC distribution grids
- Potential increase of energy efficiency, grid controllability and resiliency



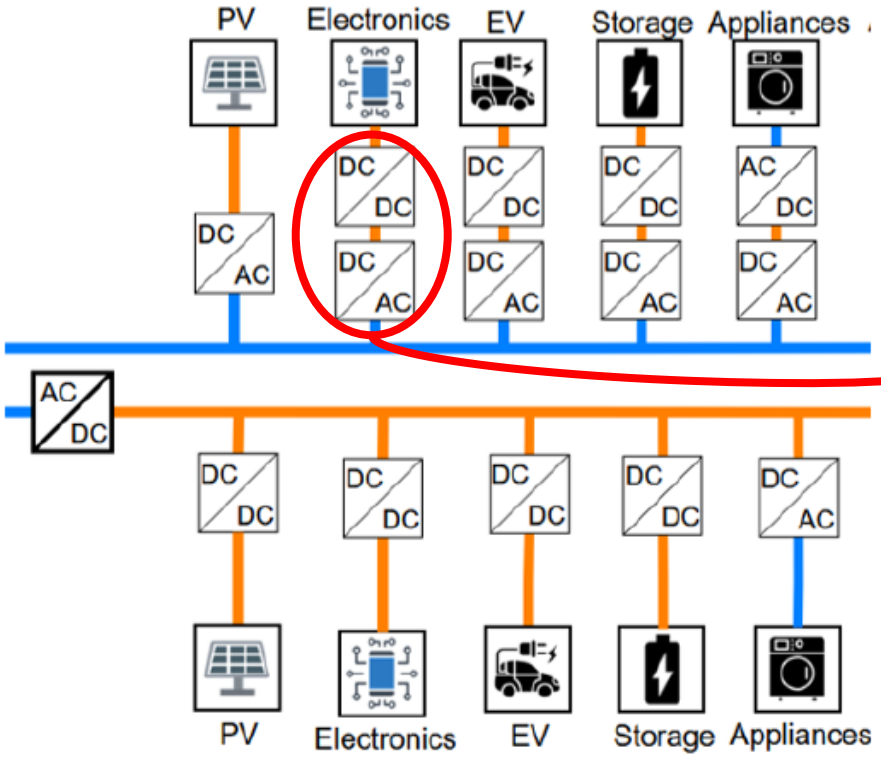
2. Energy efficiency in LVDC

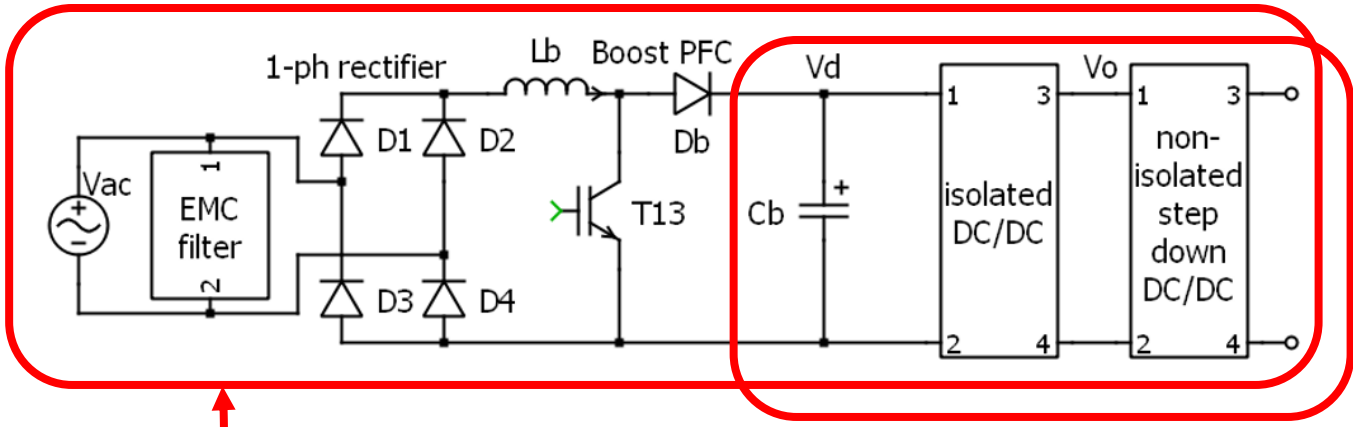
- Efficiency gains associated to the use of DC for distribution systems:

1. Power electronics converters mutualization
2. Electricity flow
3. DER Integration

2. Energy efficiency in LVDC

- Power conversion mutualization through a central Active-Front End converter (AFE)





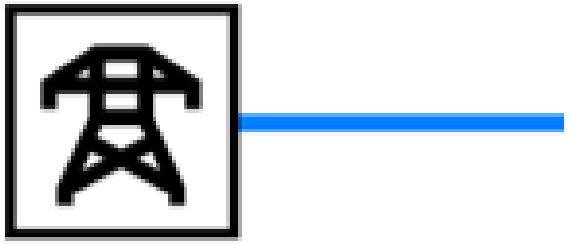
- 88% efficiency
- 93% efficiency
- **5% efficiency gain***

*[Wunder 2014] Wunder, B.; Ott, L.; Szpek, M.; Boeke, U. et al.; Energy efficient DC-grids for commercial buildings. 36th Int. Telecommunications Energy Conference (INTELEC), Vancouver (Canada), 2014, 1-8, ISSN: 0275-0473

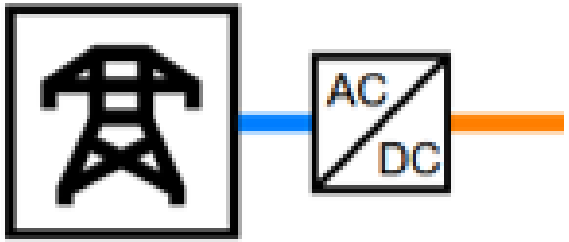
2. Energy efficiency in LVDC

- No skin effect (approximation IEC 60287-1-1)
- No reactive power

AC distribution system



P=X + Q=Y ↑ I_{total} ↑ Temperature



P=X + Q=0 ↓ I_{total} ↓ Temperature

DC distribution system

$$\delta = \sqrt[2]{\frac{1}{\pi f \mu \sigma}} \quad (1)$$

$$R_{AC} = R_{DC}\left(1 + \frac{x_s^4}{192+0.8x_s^4}\right) \quad (2)$$

$$x_s^4 = \left(\frac{8\pi f K_s}{R_{DC}10^7}\right)^2 \quad (3)$$

f: frequency (Hz)

μ: magnetic permeability of the material (H/m)

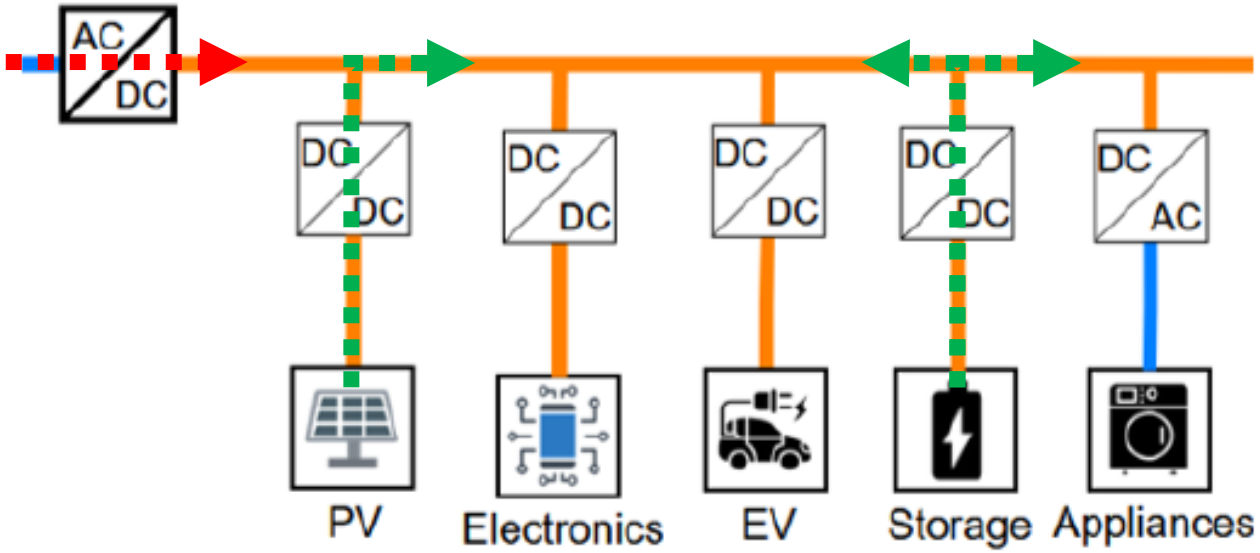
σ: conductivity of the material (S/m)

K_s: equals to 1 for round conductors

δ: skin depth (m)

2. Energy efficiency in LVDC

- Simplicity to integrate DER
- Local consumption



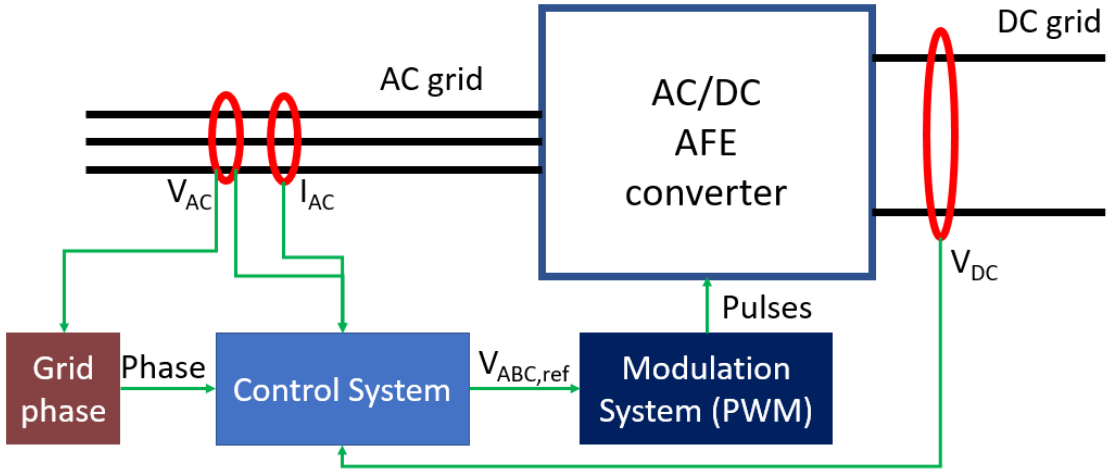
- 14% efficiency increase*
- 15% efficiency increase**

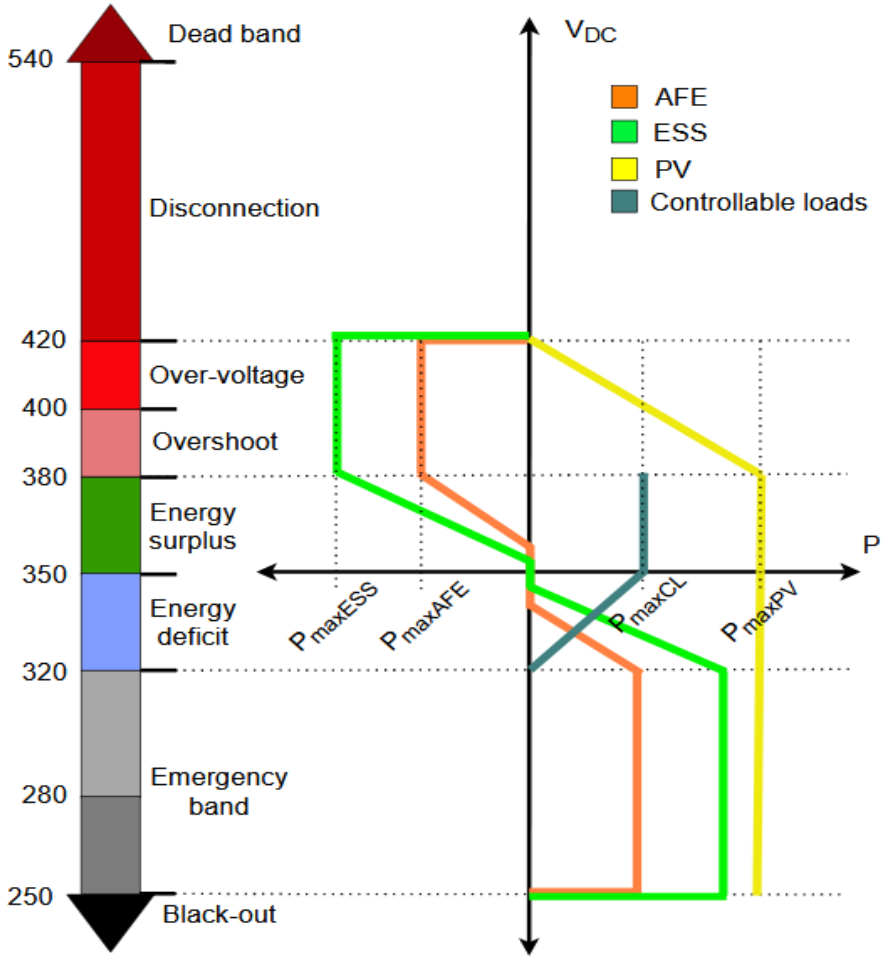
*[Alsaedi 2022] Alsaedi, A.; Alharbi, F.; Alahdal, A.; Alahmadi, A.N.M. et al.; Low voltage direct current supplies concept for residential applications. Energy Explor. Exploit., Mar. 2022, 40, 3, 1078-1097.

**[Vossos 2014] Vossos, V.; Garbesi, K.; Shen, H.; Energy savings from direct-DC in US residential buildings. Energy Build., Jan. 2014, 68, 223-231, ISSN: 0378-7788.

3. Controllability for LVDC distribution grids

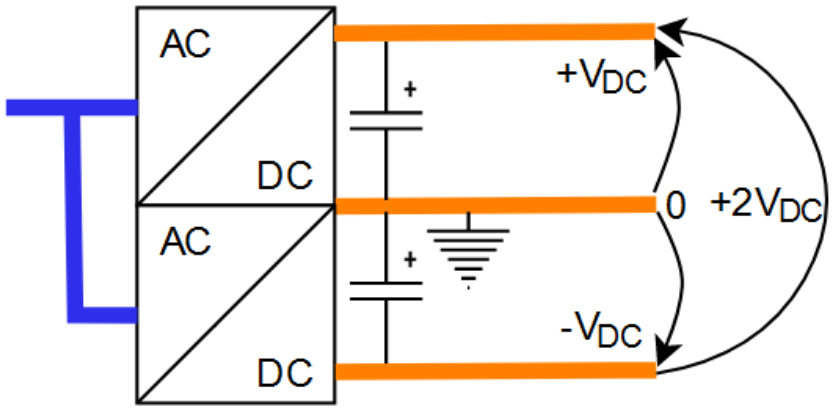
- AFEs can control the power flow and can act directly in power quality phenomena through vectorial control (Park transformation)
- Energy management control based on droop technique are easily executed

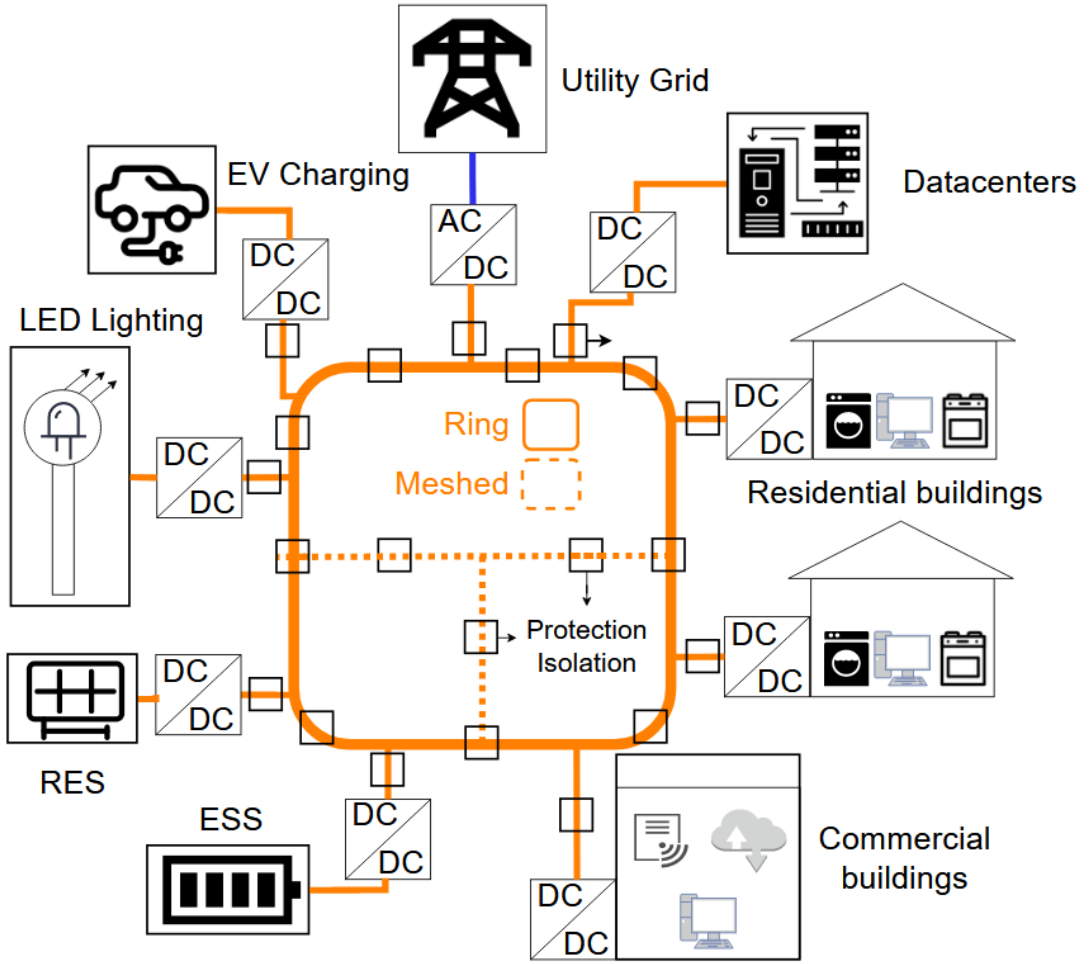




4. Synchronization and resiliency

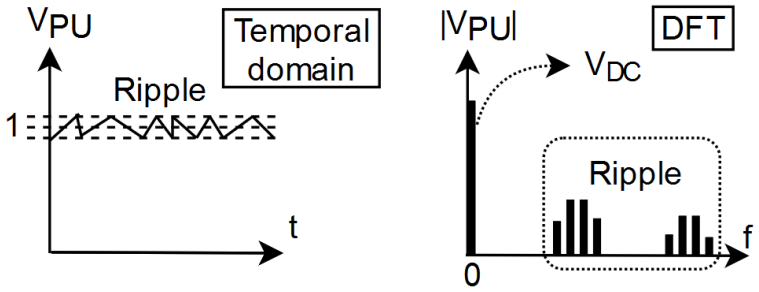
- No fundamental frequency -> no synchronization needed
- Ring-based and meshed grids
- Bipolar grid architecture

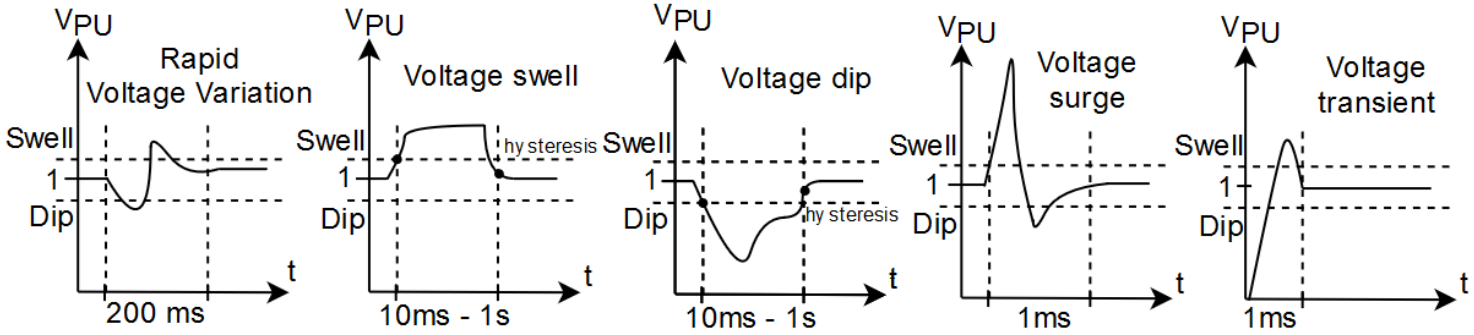


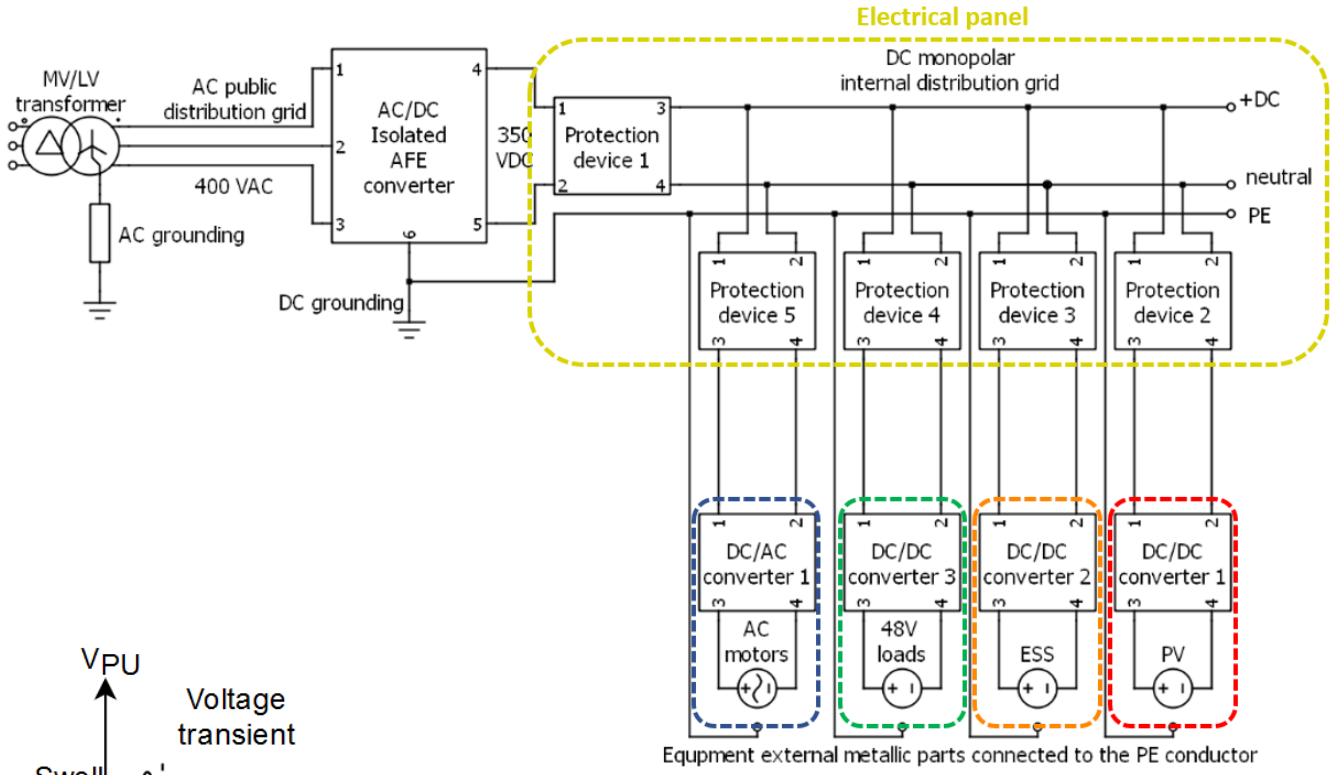


5. Challenges

- No dedicated standards in the domain
- Protection schemes and protection devices
- Power quality assessment methods







6. Conclusion

- The use of LVDC in distribution systems may be a solution to increase the presence of DER in the energy mix.
- Through RES, local consumption and converter mutualization it is possible to increase efficiency of distribution systems
- Enhanced controllability though vectorial control and simple energy management systems
- Enhanced resiliency through more complex grid architectures

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- Perspectives: understand which are the possibilities of designing a protection system for LVDC grids without compromising the economical feasibility.
- Investigate how to assess power quality indicators to guarantee a certain level of electro-magnetic compatibility

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References

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[Garbesi 2011] Garbesi, K.; Vossos, V.; Shen, H.; Catalog of DC appliances and power systems. LBNL-5364E. Berkeley: Lawrence Berkeley National Laboratory, 2011.

[Huynh 2022] Huynh, W.; Hoang, T.T.; Ukil, A.; Nair, N.K.C.; Comparison of low-voltage AC and DC distribution networks for EV charging. 7th Workshop on the Electronic Grid (eGRID), Auckland (New Zealand) 2022, ISBN: 979-8-3503-3159-2.

[Kim 2018] Kim, K.; Park, K.; Roh, G.; Chun, K.; DC-grid system for ships: a study of benefits and technical considerations, Journal of International Maritime Safety, Environmental Affairs, and Shipping, Aug. 2018, 2, 1, 1-12, ISSN: 2572-5084.

[Salehi 2019] Salehi, M.; Taher, S.A.; Sadeghkhani, I.; Shahidehpour, M.; A poverty severity index-based protection strategy for ring-bus low-voltage DC microgrids. IEEE Trans. Smart Grid, Apr. 2019, 10, 6, 6860-6869, ISSN: 1949-3053.

[Vossos 2014] Vossos, V.; Garbesi, K.; Shen, H.; Energy savings from direct-DC in US residential buildings. Energy Build., Jan. 2014, 68, 223-231, ISSN: 0378-7788.

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