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MULTI LEG
SMART CHARGING INFRASTRUCTURE

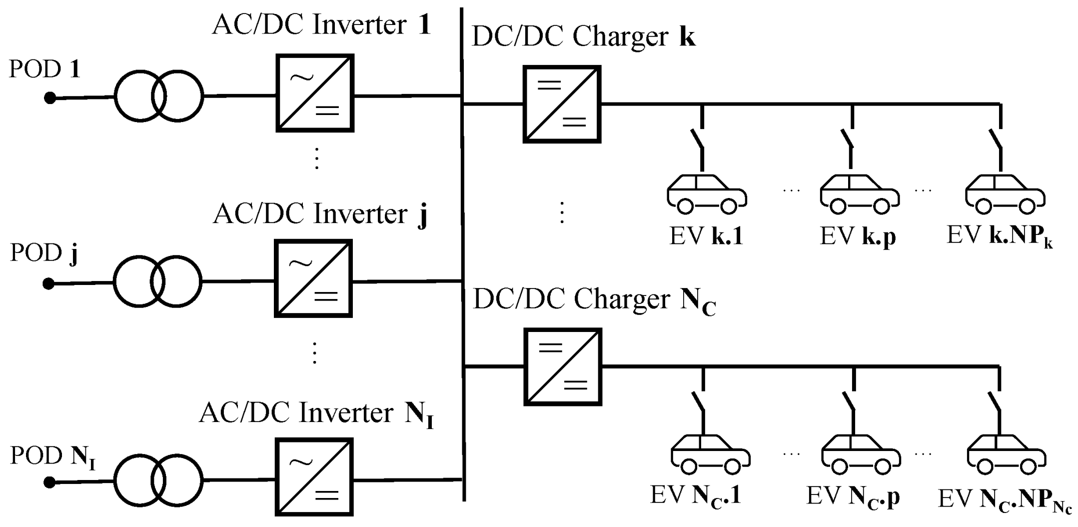
Definition and key aspects

PRESENT CONTEXT

1. **Potential high impact of charging infrastructures on distribution grids** (high power demand during peak hours for MV/LV networks, e.g., the evening)
2. **Charging tariffs:** energy delivered + connection to the infrastructure (to encourage the vehicle to leave the infrastructure free when the charging process ends) - **Inconvenience for end-users**
3. **Engagement of end-users in electrical network regulation is a pillar**
4. **Different types of charge:** fast charge vs. low-power charge. **Do they really require different infrastructures?**
5. **Huge number of vehicles means a large equivalent storage device** (4 M vehicles, 70 kWh/vehicle, 10% of vehicles connected means 28 GWh) – **Relevant resource for increasing electrical network hosting capacity**

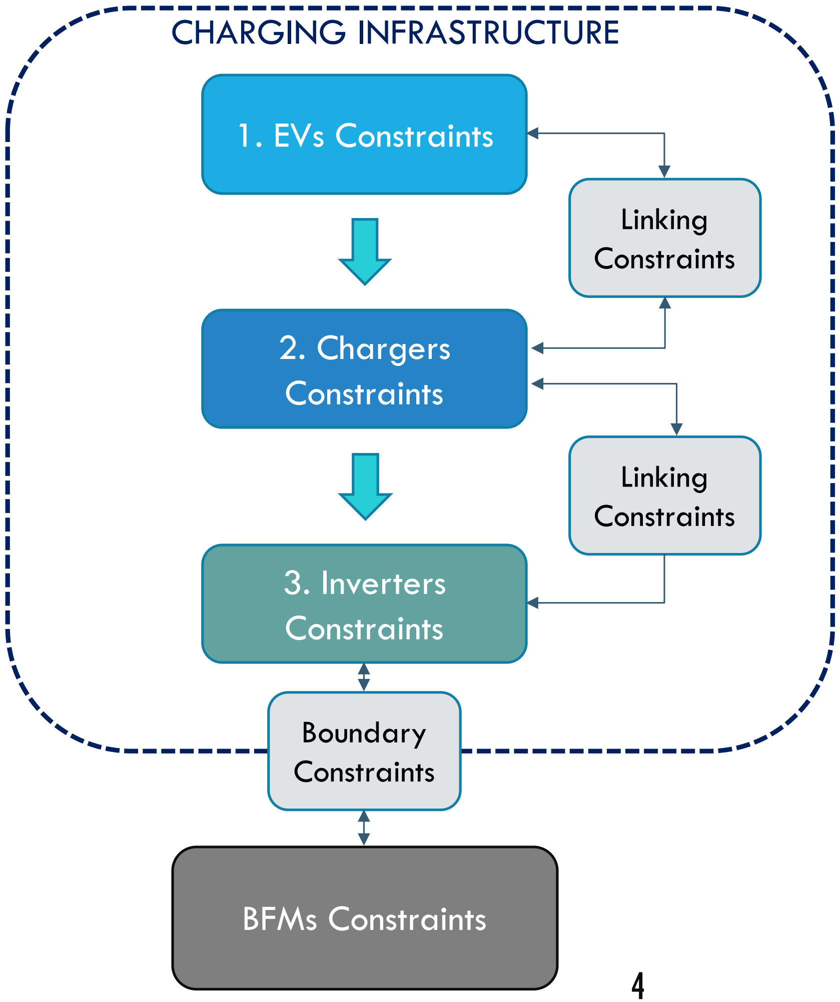
MULTI LEG SMART CHARGING INFRASTRUCTURE (MLSCI): FEATURES

- ✓ **Fast DC Charging Station:** high-power DC/DC chargers can provide fast recharge (one vehicle at a time). Several vehicles are sequentially connected to the same DC/DC charger
- ✓ **V2G:** chargers can control bi-directional power flows with the DC bus
- ✓ **AC Meshing:** bi-directional inverters can share charging demand and controllably exchange power between different distribution feeders through MV PODs (with no relevant consequences on the effectiveness of network protection)
- ✓ **Reactive power for network voltage support:** Availability of reactive power to be exchanged with distribution feeders



MULTI LEG SMART CHARGING INFRASTRUCTURE (MLSCI): CONSTRAINTS

- ✓ **Vehicles:** charging/discharging rated power, required final SoC, target charging time, admitted SoC variation, charging/discharging efficiency, V2G availability
- ✓ **DC/DC chargers:** rated power, charger efficiency, only one vehicle connected each time instant
- ✓ **AC/DC inverters:** apparent rated power
- ✓ **Distribution network:** admitted voltage variation range, resolution of line congestion (in the distribution feeders connected to the MLSCI)



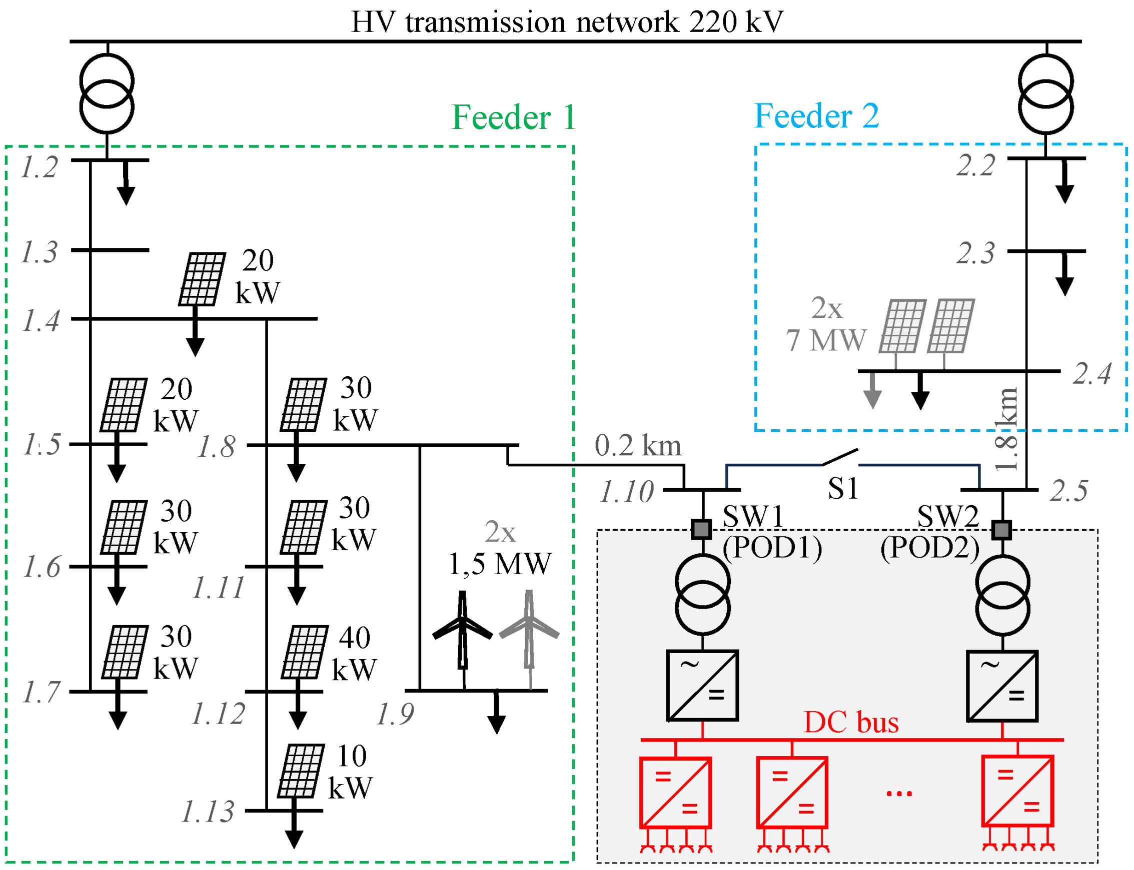
MULTI LEG SMART CHARGING INFRASTRUCTURE (MLSCI): OBJECTIVES

Multi-period optimization with possible objective functions:

- ✓ **Technical domain:** minimizing overall losses (vehicles, charging infrastructure and distribution network) while respecting operating constraints [kWh]
- ✓ **Economic domain:** minimizing overall network costs, including charging tariffs, while respecting operating constraints [€]
- ✓ **Flexibility services to the network:** definition of flexibility amount, shape and costs to participate in local ancillary markets [kWh - €]

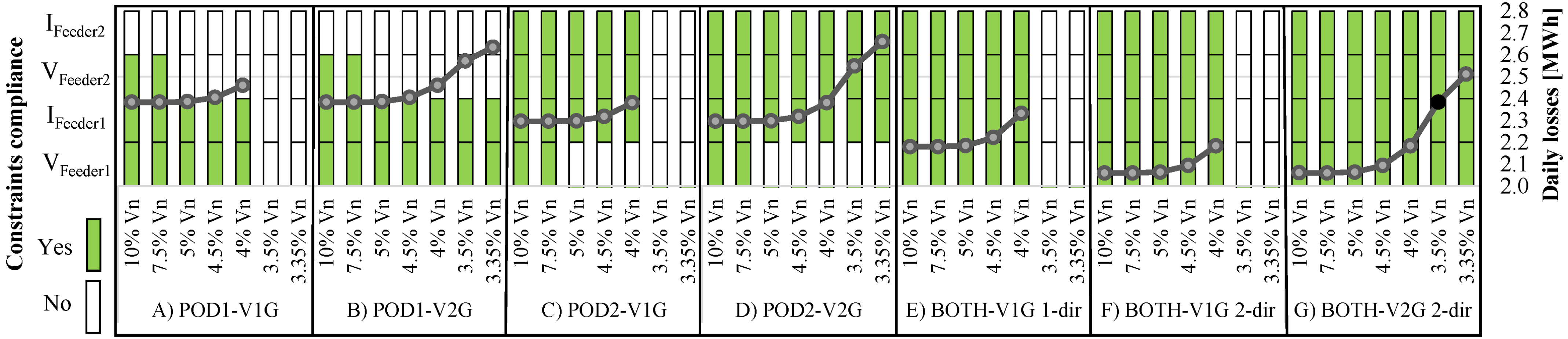
CASE STUDY

- European MV distribution network benchmark (Cigrè)
- **MLSCI with 2 PODs** (1.6 MVA each)
- 10 DC/DC chargers, 100 kW each
- **2 groups of 40 vehicles to be charged** (90 kWh, initial SoC 30%, target SoC 80%)
- **7 scenarios:** only POD1 (1&2), only POD2 (3&4), both PODs (5-7), with/without V2G



LOSS AND CONSTRAINT COMPLIANCE

BENEFIT ANALYSIS AND CONCLUSIONS



- ✓ MLSCI can **regulate voltage and solve congestions in the entire distribution network** when connected to both the feeders
- ✓ **Sharing the charging demand between different PODs** reduces overall losses
- ✓ **V2G and bi-directional operation of converters** increase the voltage control within smaller admitted ranges and further improve **system efficiency**
- ✓ Vehicles are not forced to be moved once the charging process ends – **Benefits in end-user experience**
- ✓ **Incentives (charging discount)** for leaving vehicles connected to participate in ancillary services provision

Bignucolo, F.; Mantese, L. Controllable Meshing of Distribution Grids through a Multi-Leg Smart Charging Infrastructure (MLSCI). Energies 2024, 17, 1960.
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