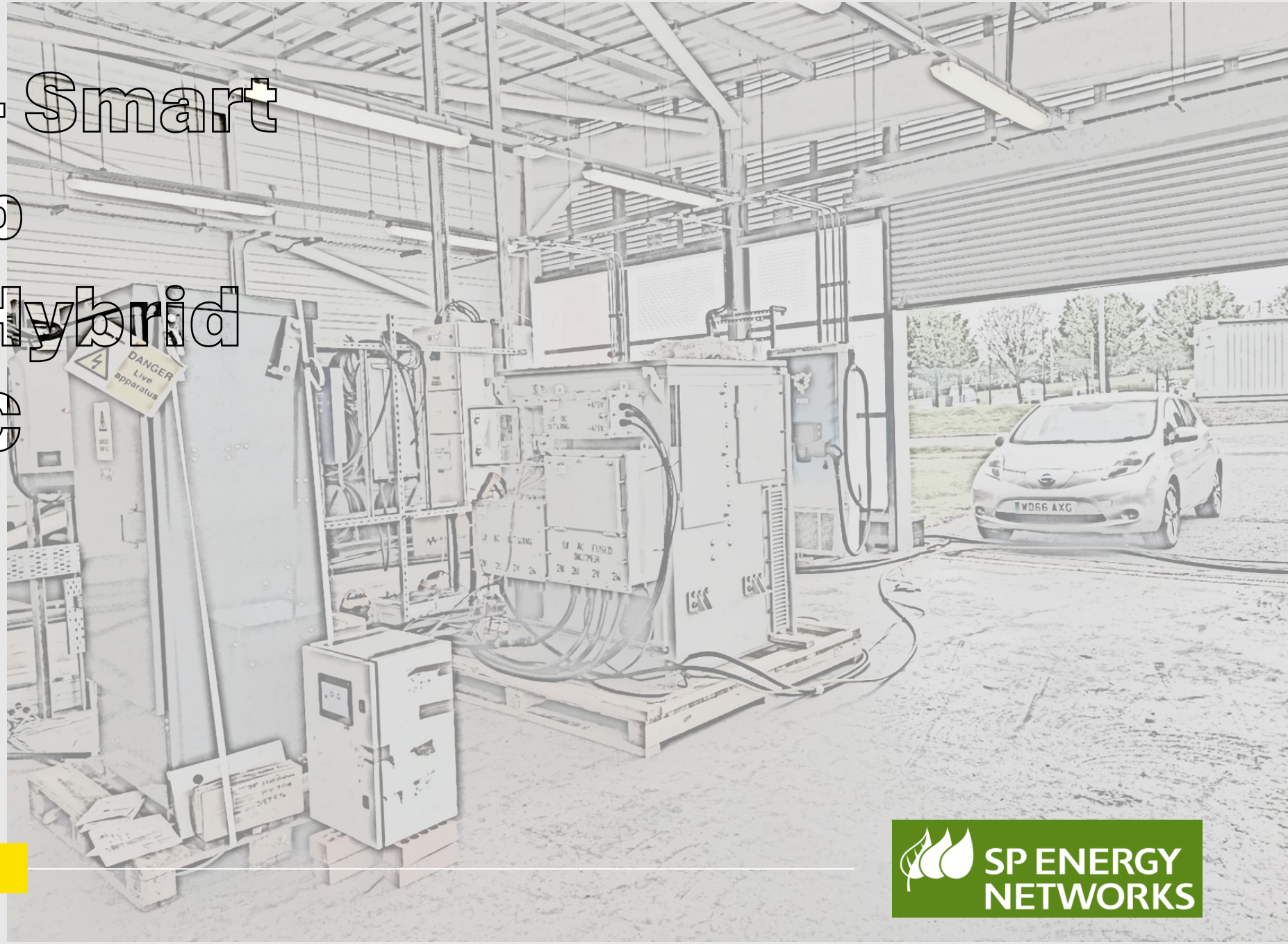
LV Engine – Smart Energy Hub Providing Hybrid LVDC/LVAC Networks

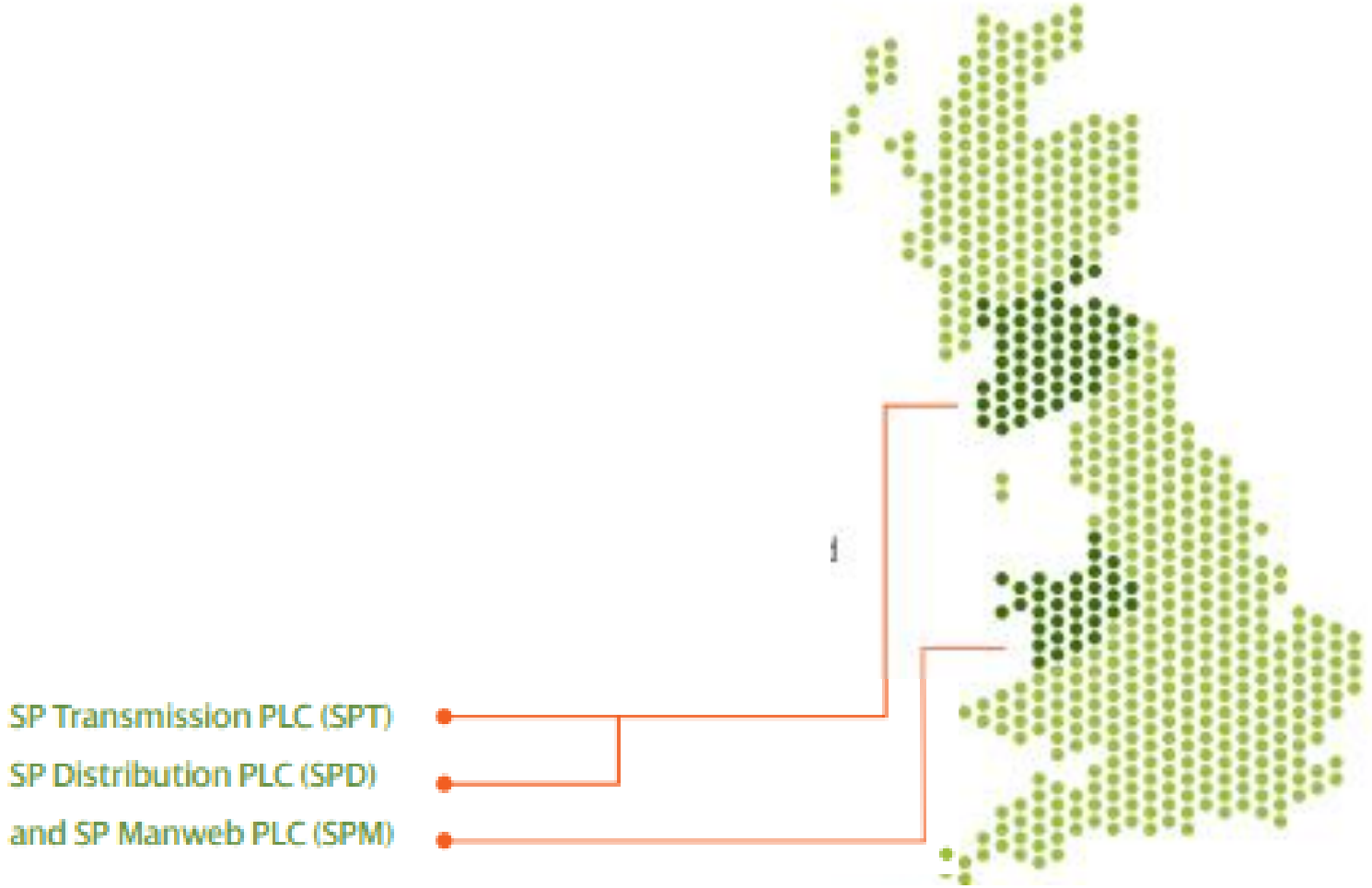


Cigre UK, August 2023

SP ENERGY NETWORKS

SP Energy Networks

- Network Operator for Transmission and Distribution in Central and Southern Scotland
- Distribution Network Operator in North Wales, Cheshire and Merseyside
- Over 44,000km Overhead Lines and 65,000km Underground Cables
- Over 3000 substations
- A Total of 3.5 Million Customers Supplied



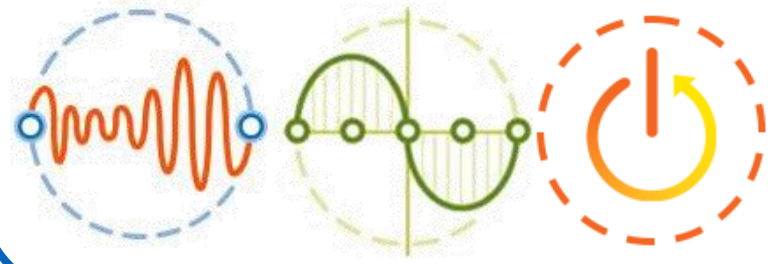
Innovation Strategy

The Future Networks team are delivering on our innovation strategy.

We have industry-leading expertise in two major fields which significantly impact the future of the distribution and transmission industries. We have been able to develop these skills and expertise by successfully delivering strategic innovation projects.

Black Start

We have consistently built our portfolio of Black Start projects since 2015, working with a range of partners to build expertise and capabilities.



Power Electronics

We have developed and delivered a portfolio of projects covering the implementation of power electronics across a wide range of voltages on the transmission and distribution networks.

Transmission Network Reliability/Security

VISOR

Providing greater visibility & understanding of network state and assets, and increasing network reliability

FITNESS

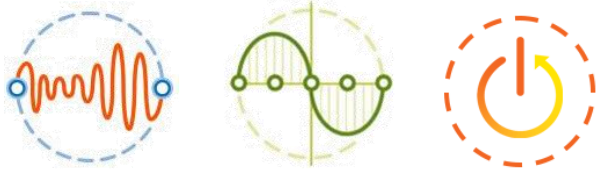
Delivering an efficient and effective digital substation, increasing interoperability and flexibility between substations

Distributed Restart

Exploring how distributed energy resources can be used to support the network and restore power to the network

Synthesis

Use advanced analytics and real-time control to enable rapid response in reaction to system disturbances



£13.59m further investment for SPT (p. 112 of RIIO-T2 Business Plan) and estimated at £40m for other GB Transmission business

£54m investment in RIIO-2 Business plan through digital substations being installed at Westfield and Hunterston

£5m Green Recovery Fund: Synergy

2023-SIF: Black-start from the offshore

Power Electronics

Phoenix

Combining Synchronous condensers with static compensator technologies to manage reduced inertia and voltage control on the Transmission network

Angle-DC

Adapting existing power electronics to enable a Medium Voltage DC (MVDC) link to Anglesey, allowing increased renewable generation integration

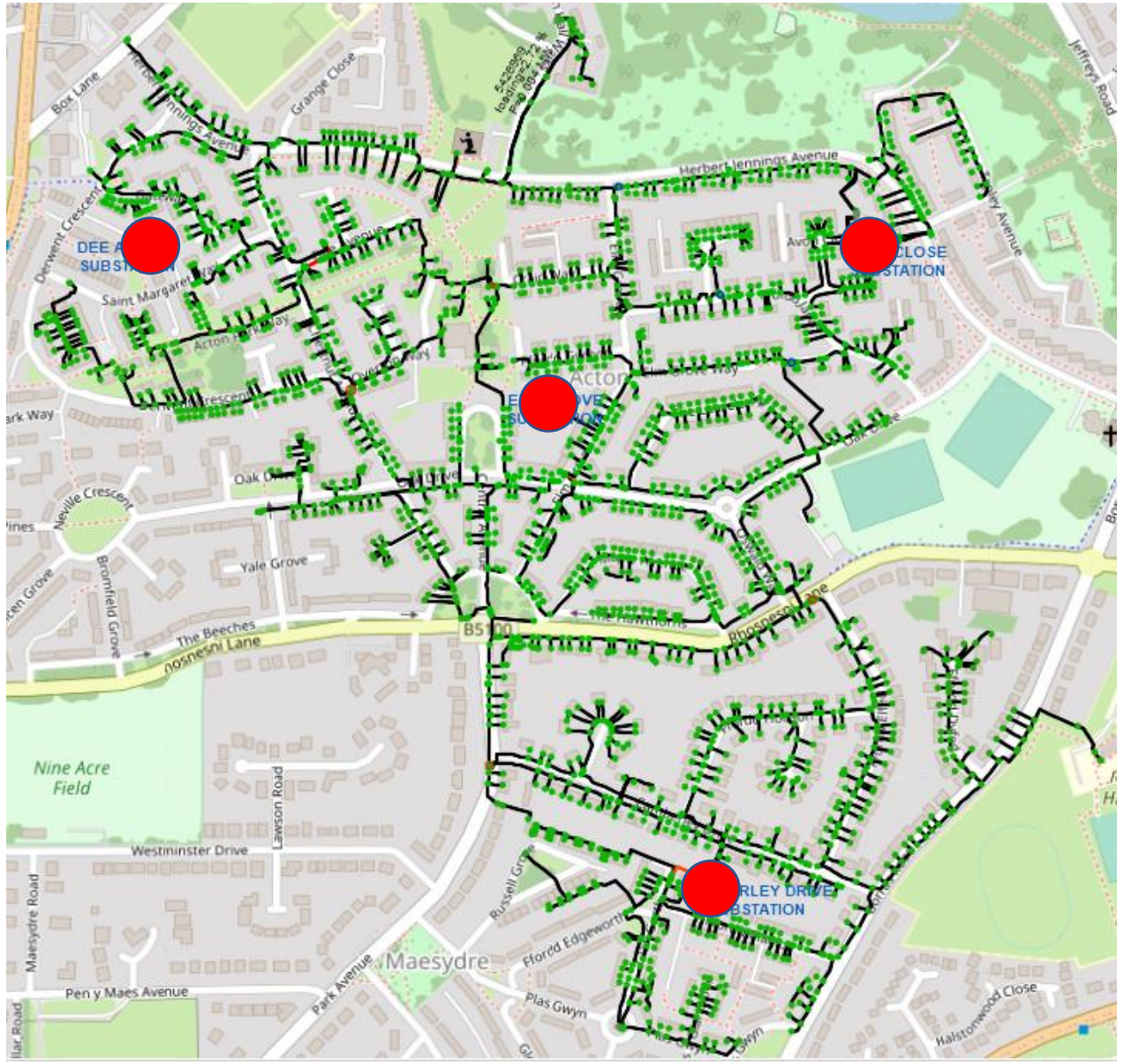
LV Engine

Network trial of innovative Smart Transformers to facilitate the connection of low carbon technologies, such as EV charging and heat pumps

£120m investment in RIIO-2 Business plan through implementation of synchronous condensers at Eccles

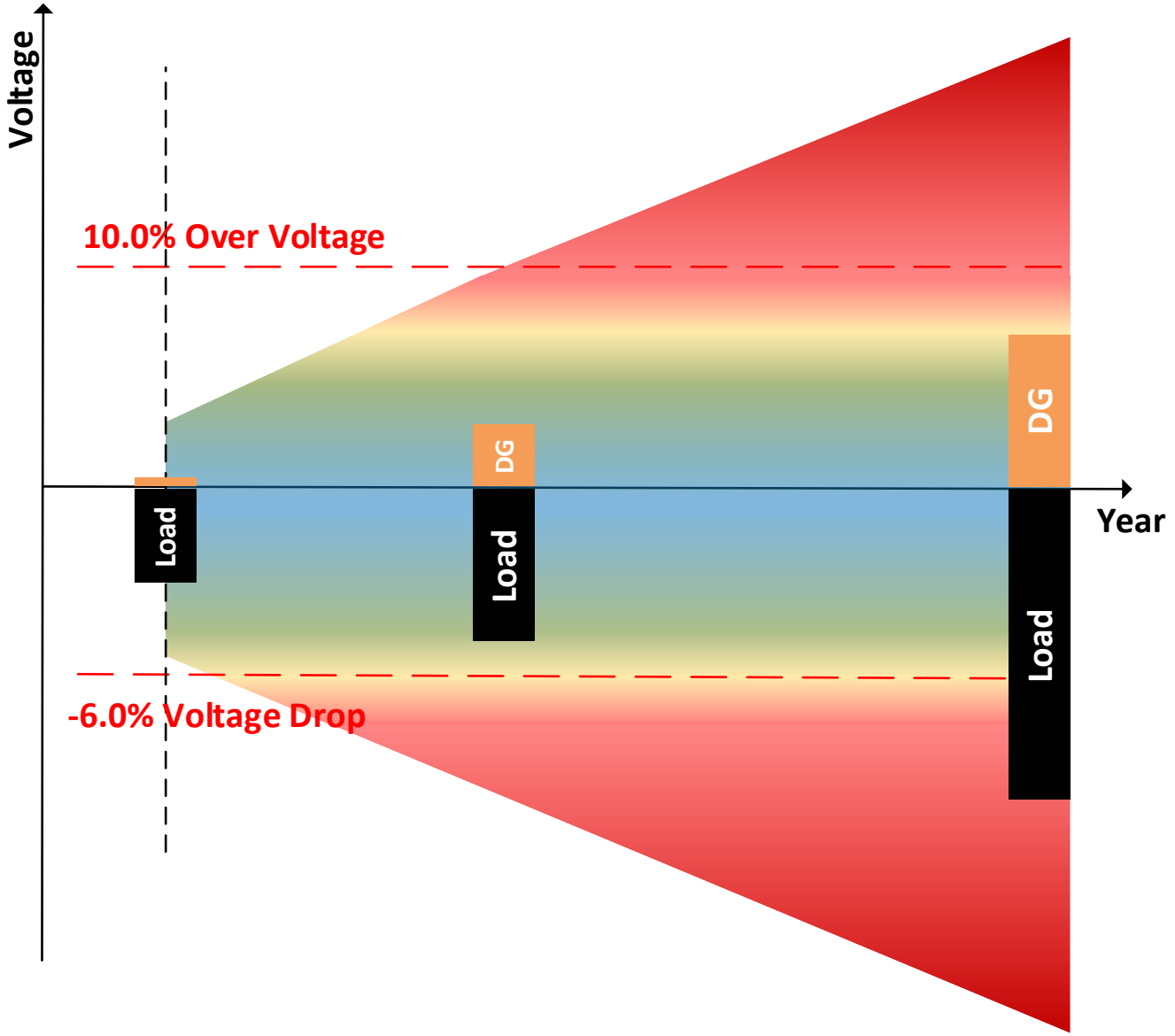
Three Further sites planned to roll out LV Engine Technology within RIIO-ED2

LV Network operation - background

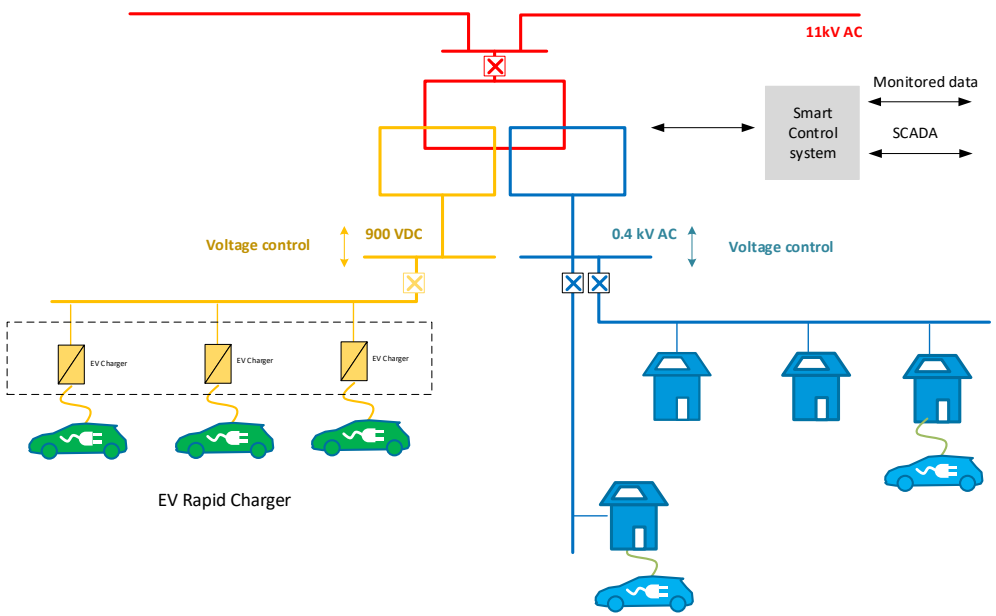


Distribution Networks are experiencing growing voltage and thermal issues.

- Increase in demand and LV DG connections
- The additional demand caused by EVs' and heat pumps'
- Uncertainties in LCTs growth (when, where, how much..)
- Increasing demand for the supply of DC power



LV Engine



A globally innovative trial of power electronic technologies within the distribution network at secondary substations (11/0.4kV) with the objective of enhancing network flexibility and controllability to **release additional capacity** within our existing network infrastructure and **facilitate the connection of Low Carbon Technologies such as Electric Vehicles, PVs, and Heat pumps.**

£8.3m Project funded through NIC mechanism
Completion by end of 2024

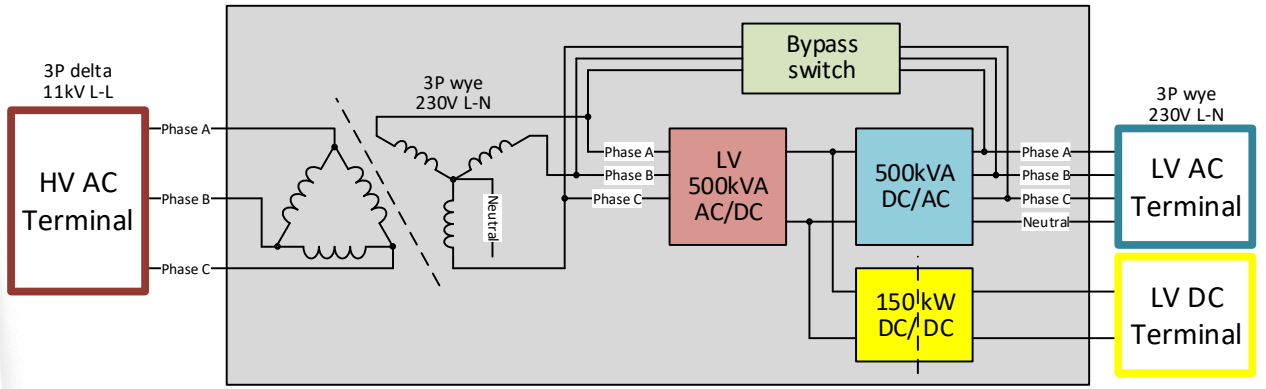
Better Use of Assts	Intelligent LV Voltage Regulation	Public LVDC Network
capacity Sharing between neighbouring substations and sharing on AC and DC	Voltage regulation for each phase based on voltage profile along the LV feeder	Provision of low voltage DC network for creating headroom, better efficiency, improved voltage profile and thermal rating
Increases available transformers capacity to supply electricity demand	Alleviates LV voltage depression due to increase demand and generation	Allows EV rapid chargers to connect directly to a DC network – smaller size units, better efficiency, better power quality

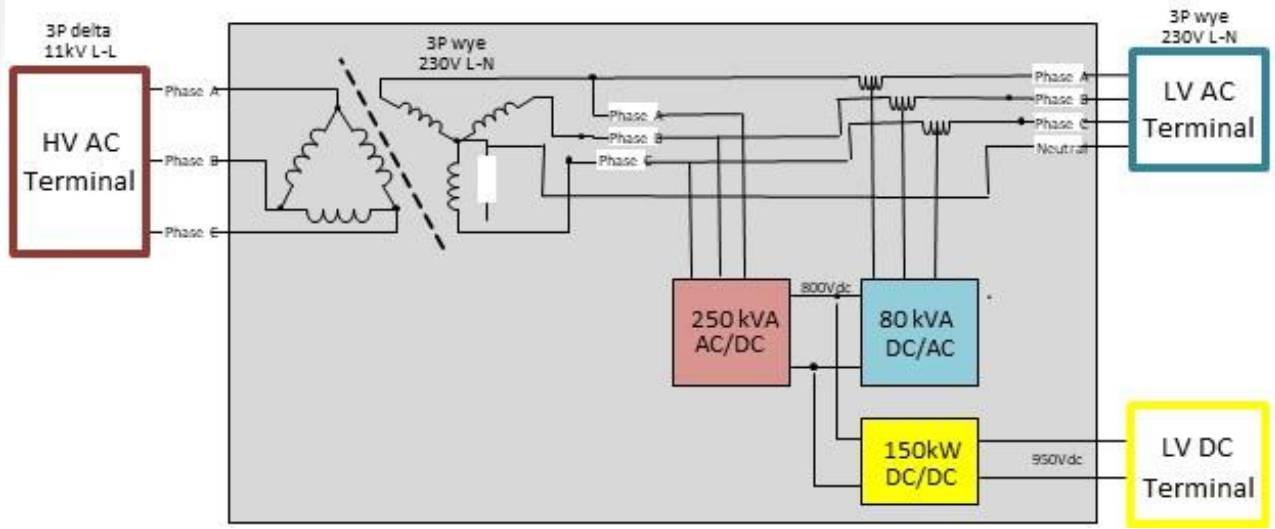
Project partners

Falkirk Council

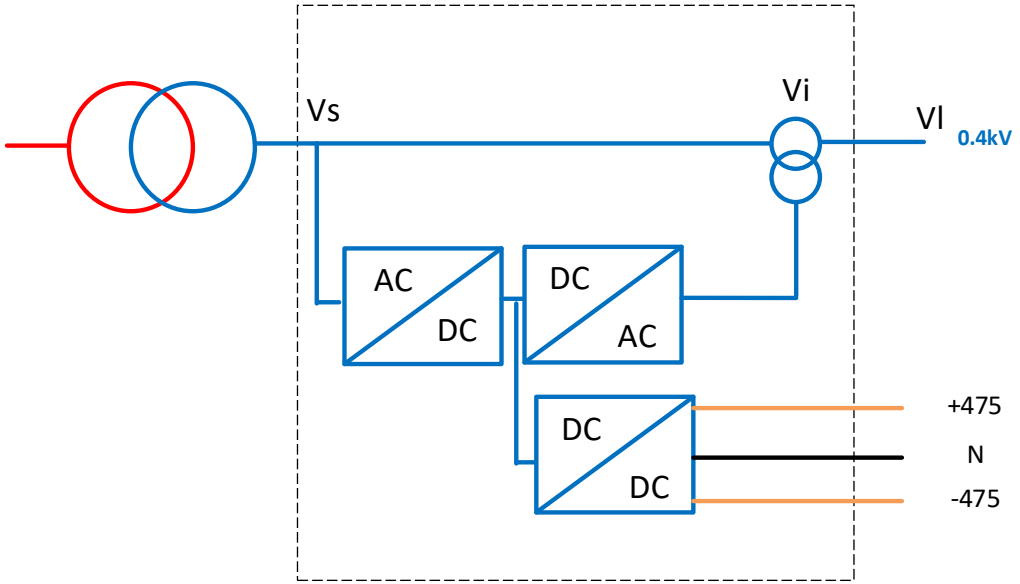
Design optioneering

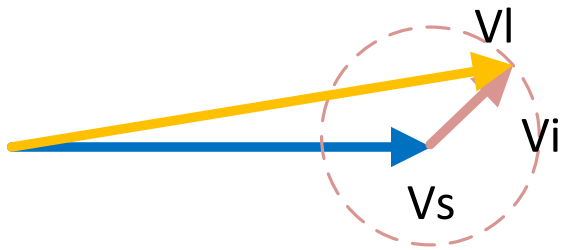
- **Improved performance during the fault**
- **Improved efficiency**
- **Smaller power electronics power rating**
- **Bypass possibility**
- **Smaller dimensions**
- **Improved overall reliability**





Products – PED (UPFC)





UPFC - services

- Voltage control :
  36.8 V boost/buck
- Power factor correction :
  0.9 (lead/lag) to unity
- Load imbalance cancelation:
  30%
- LV DC supply :
  150 kW
- Control power flow:
  P and Q control

Priority	Total load	Total Imbalance cancelation	PF target	Voltage control (boost/buck)	DC
1	500kVA	30%	Unity	36.8V	150kW
2	500kVA	20%	Unity	36.8V	150kW
3	500kVA	10%	Unity	36.8V	150kW
4	500kVA	0.0%	Unity	36.8V	150kW
5	500kVA	0.0%	Load PF	36.8V	150kW

Manufacturing process

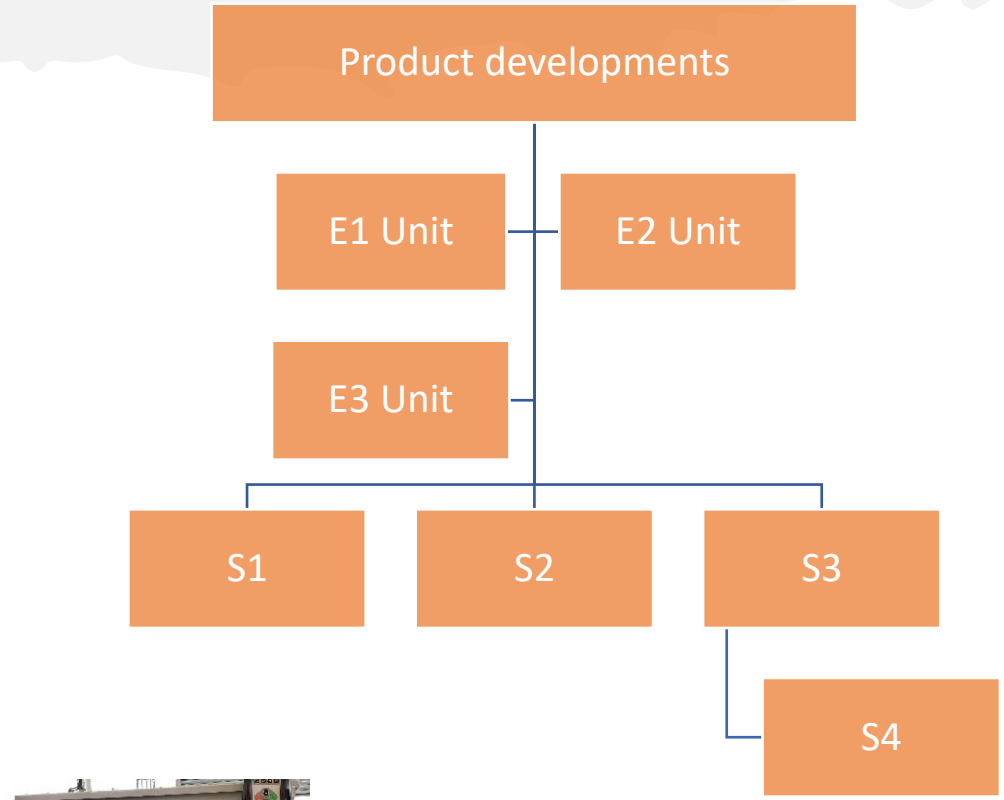
Project inception
- Reviewing SST technical specification
- Identifying the critical and flexible technical requirements
- Understanding UK specific policies and standards
- Developing initial solutions/topologies

Initial Design
- Developing product building blocks design
- Identifying the design trade-offs and design optioneering
- Carrying out limited desktop simulations for performance demonstration – continuous and faulted scenarios
- Initial thermal management requirements

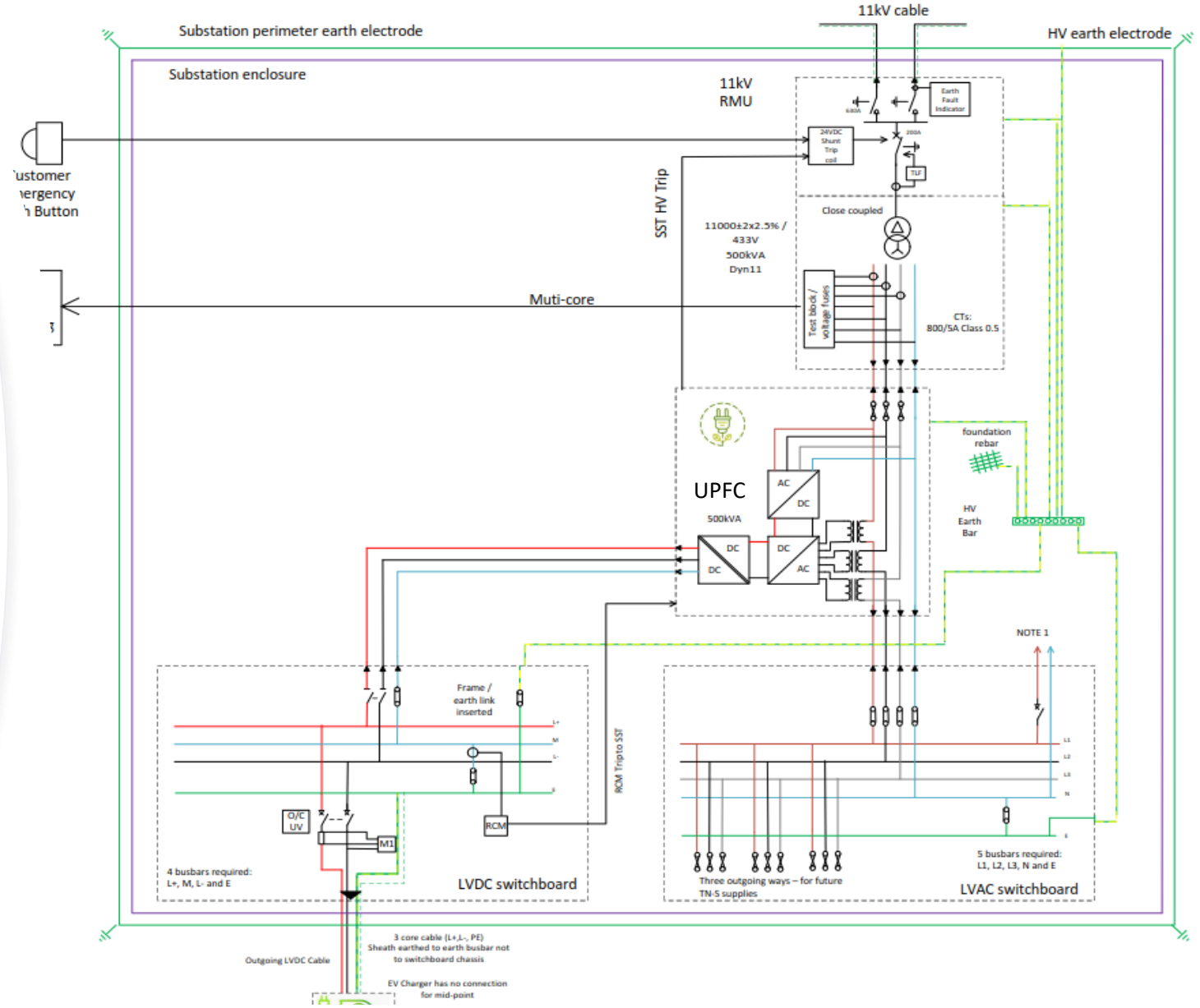
Enhanced Design
- Developing components (magnetics, power electronics etc) technical specification
- Developing control strategy in different network scenarios
- Designing plant interfaces and terminations
- Detailing protection strategy – Internal and external faults
- Thermal management and detailed mechanical layout design
- Supply chain/partner identification and component ordering

Prototyping
- Carrying out Benchtop testing - Component tests, module tests
- Confirming mechanical design and thermal validation
- Carrying out enhanced DSP coding, control calibrations and finalising I/O schedules
- Finalising factory test schedule and planning

Manufacturing
- Building and testing enclosure
- System assembly, components fitting, wiring, labelling – production quality tastings
- High voltage and insulation testing
- Carry out factory testing and modifications where required
- Complete documentations (tests results , O&M etc)

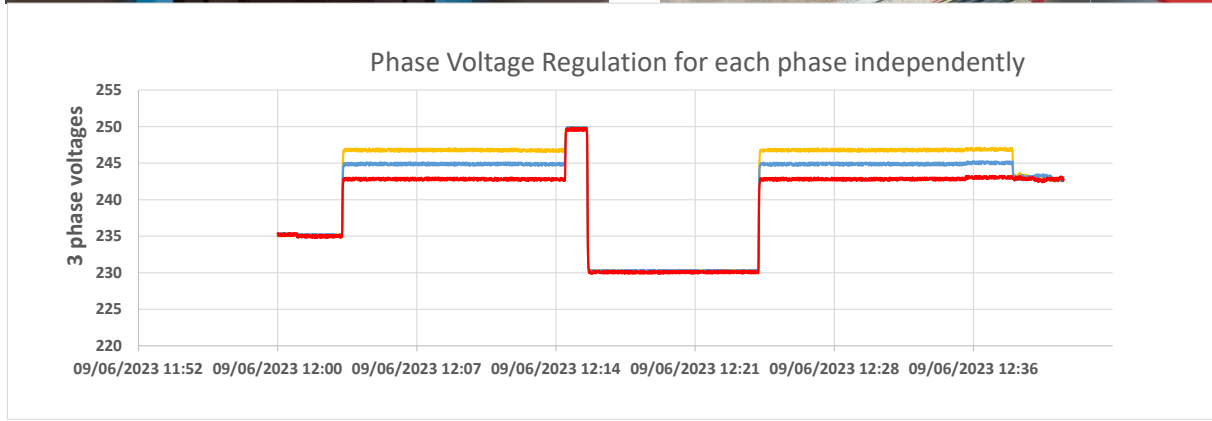


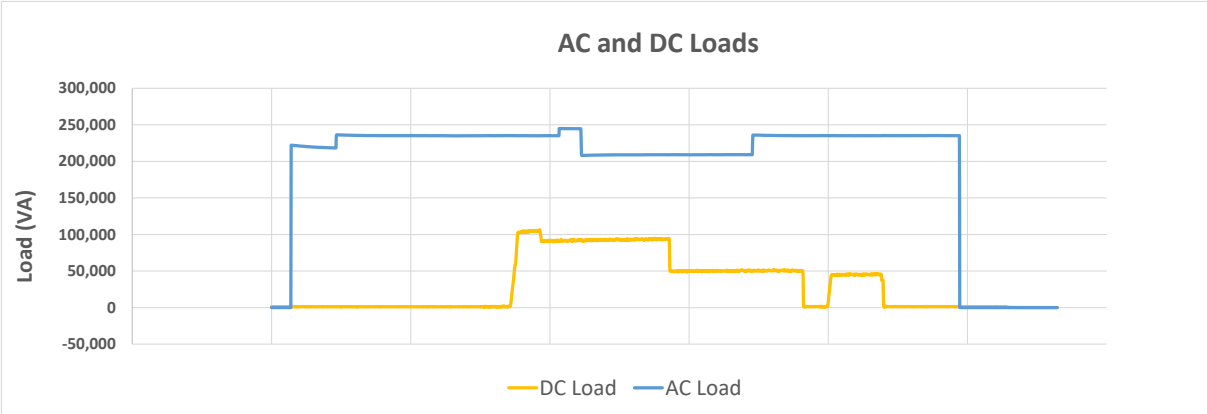
Electrical Design



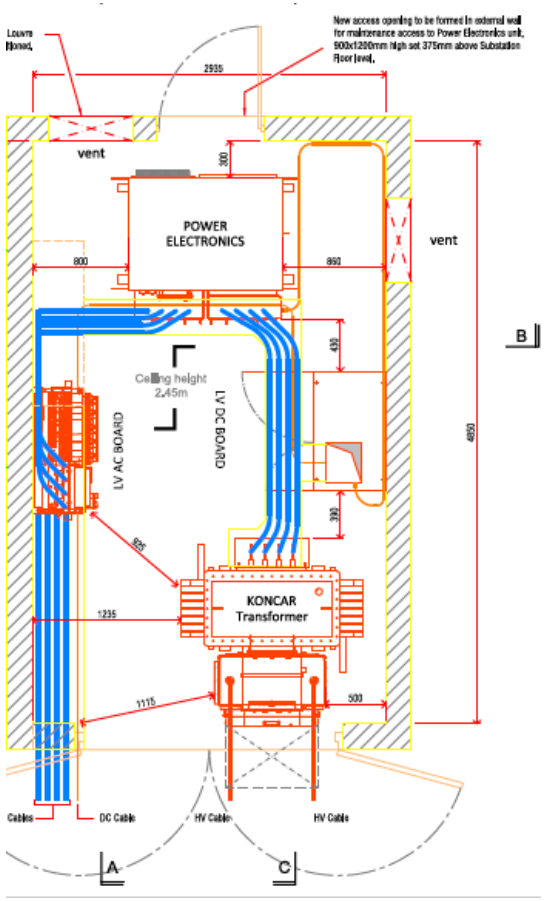
LV Engine test bay in PNDC 2023

Supplying AC and DC load

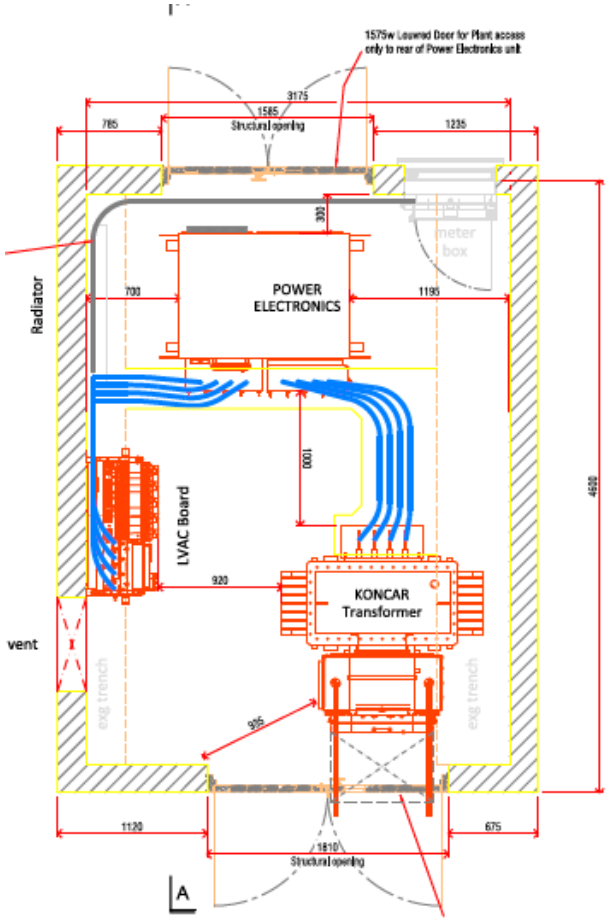




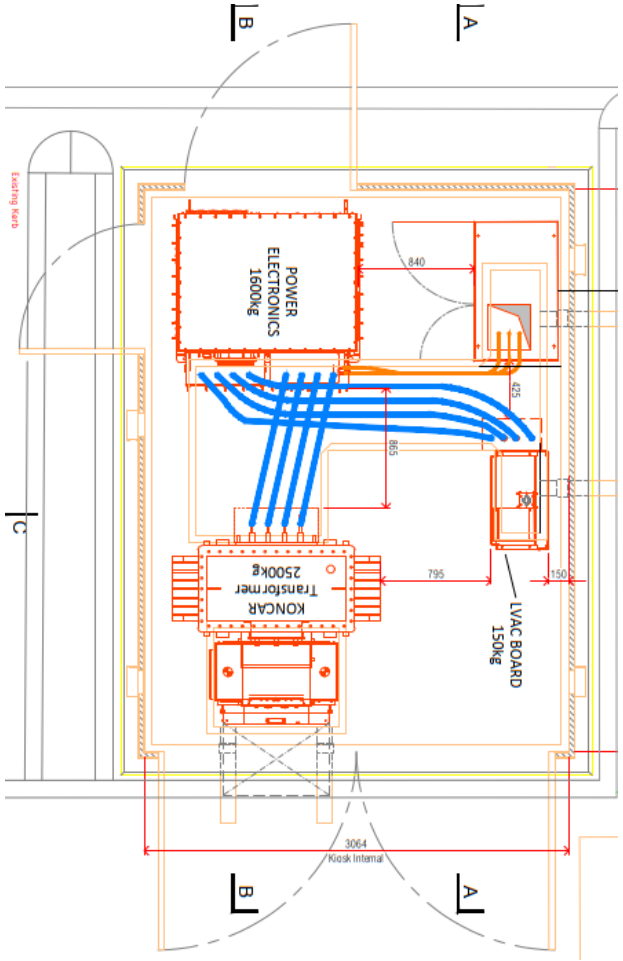
Trial sites



Site 1



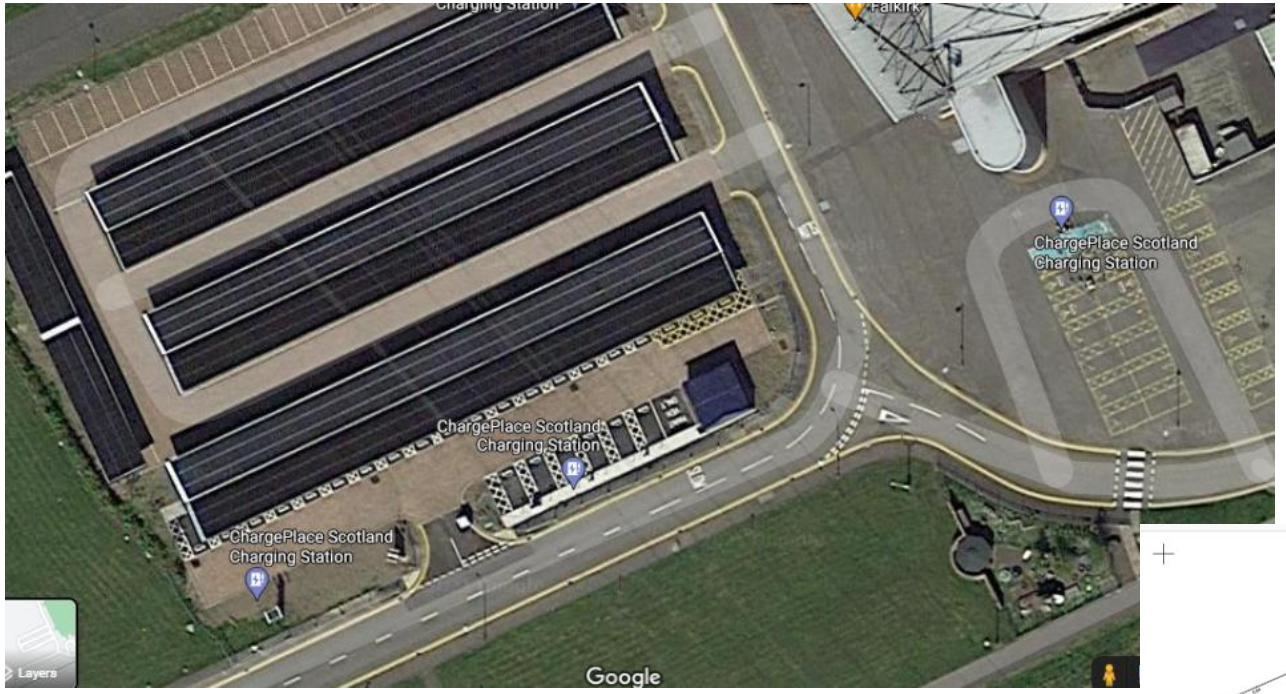
Site 2

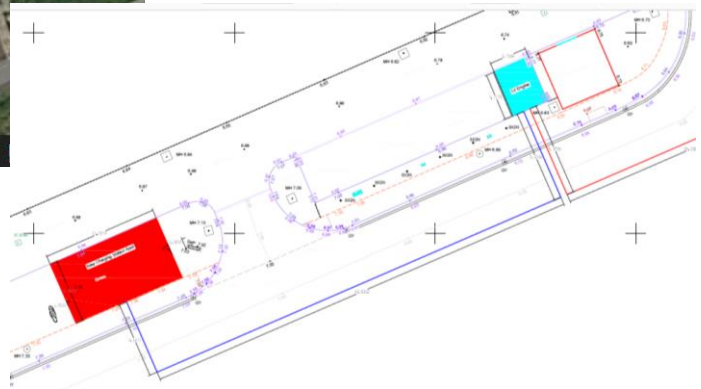


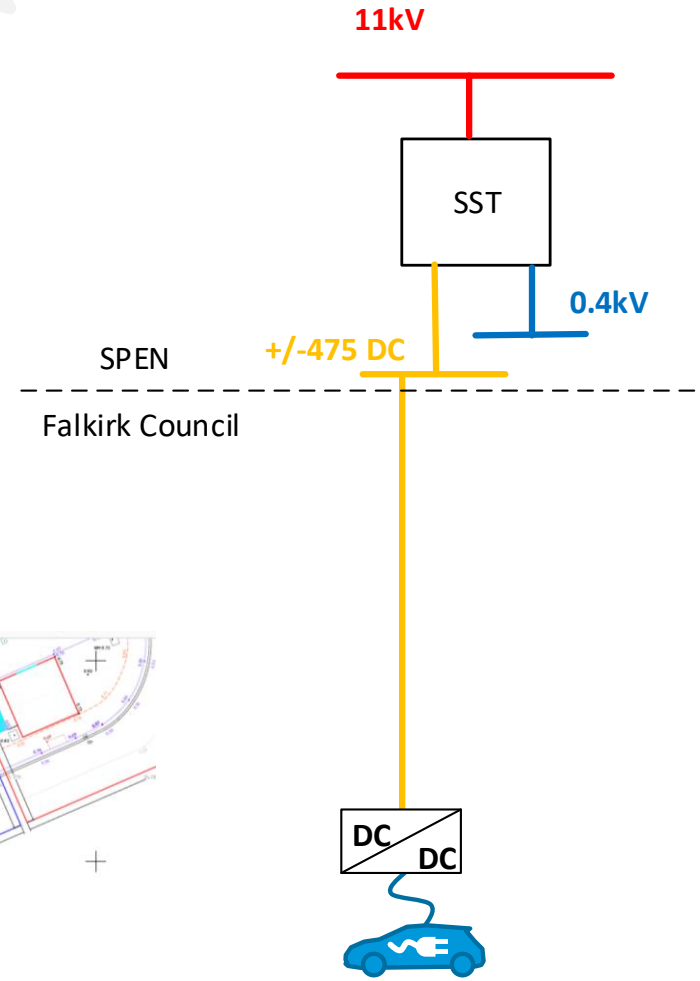
Site 3

Trial sites

Supplying an LVDC customer (150kW ultra-rapid EV)







Challenges in LVCB protection

- The exiting DNO LV protection solutions are solely based on fuse or LVCB overcurrent protection

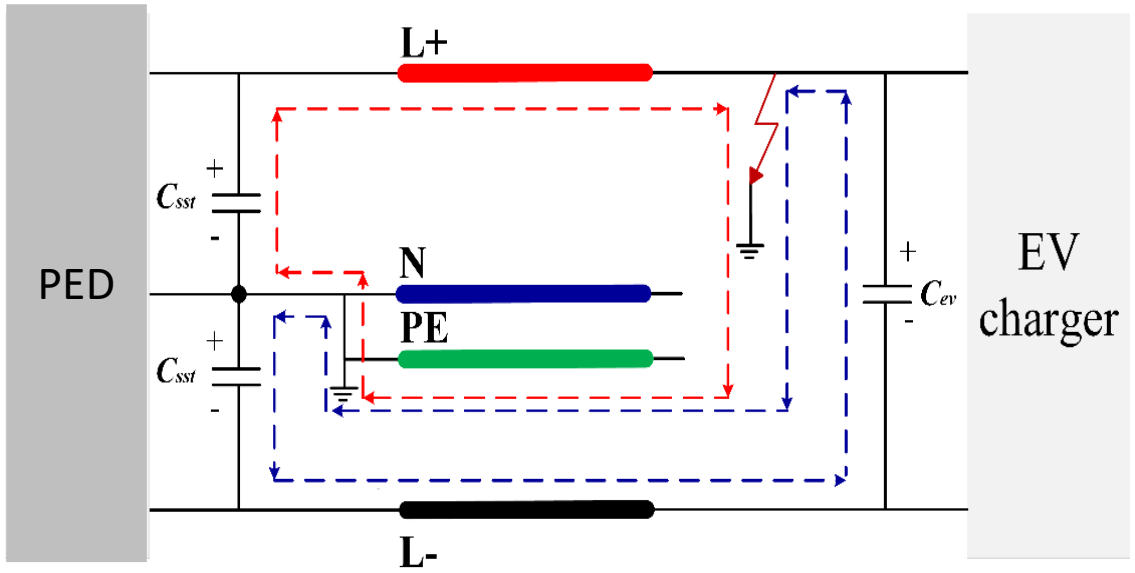
- Relying on overcurrent protection means overdesigning the power electronics unit to provide adequate current. Not an optimum solution resulting in larger and more expensive converter

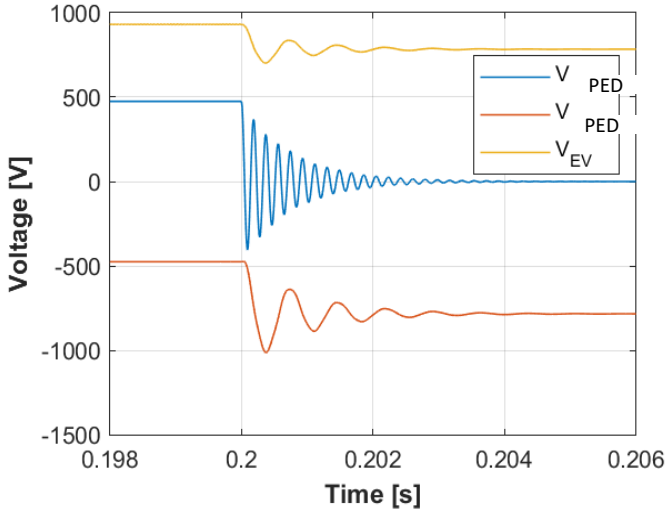
- commercially ready LVDC CBs and switch disconnectors are mainly MCCBs supplied by very limited companies - up to 1000VDC

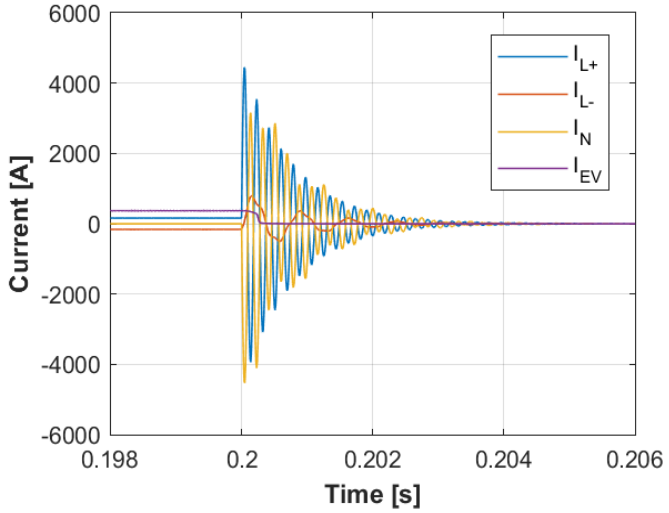
- LVDC Switchgear standards have not been used or adapted by distribution network operators. IEC 61439-2 for DC switchgear.

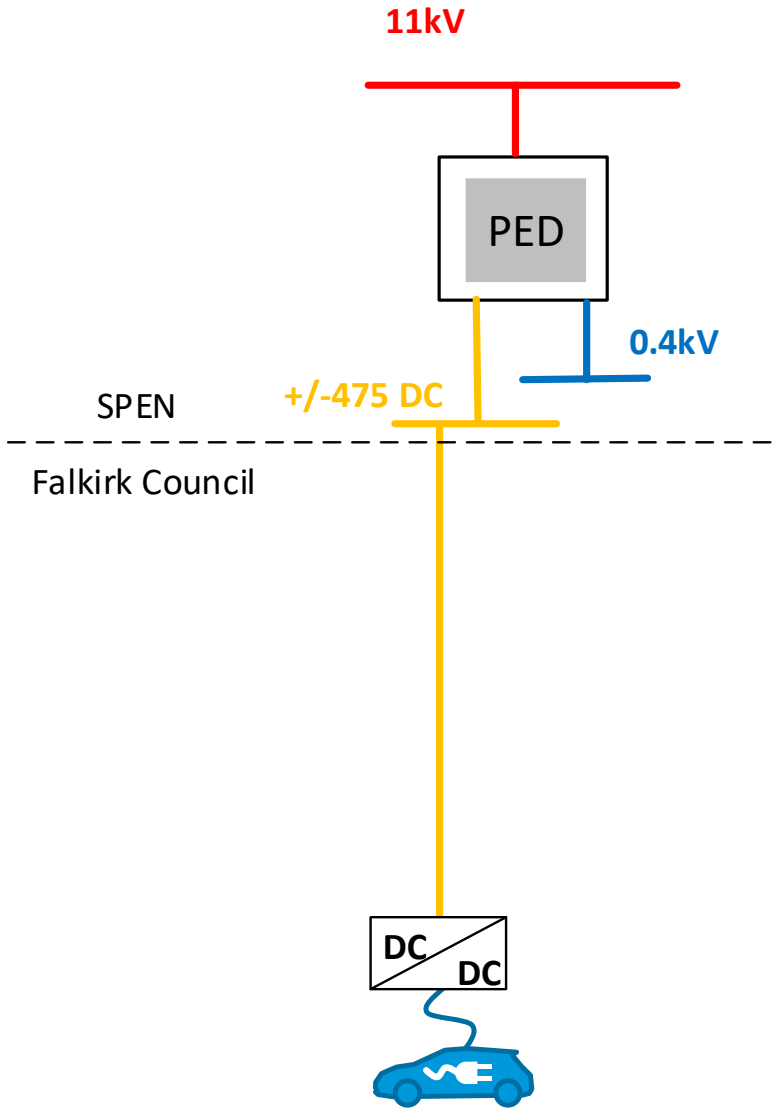
- LVDC short circuit current is very different from a typical AC short circuit current – very fast transient (<1ms) peak with current decays to zero in < 5ms

LVDC fault

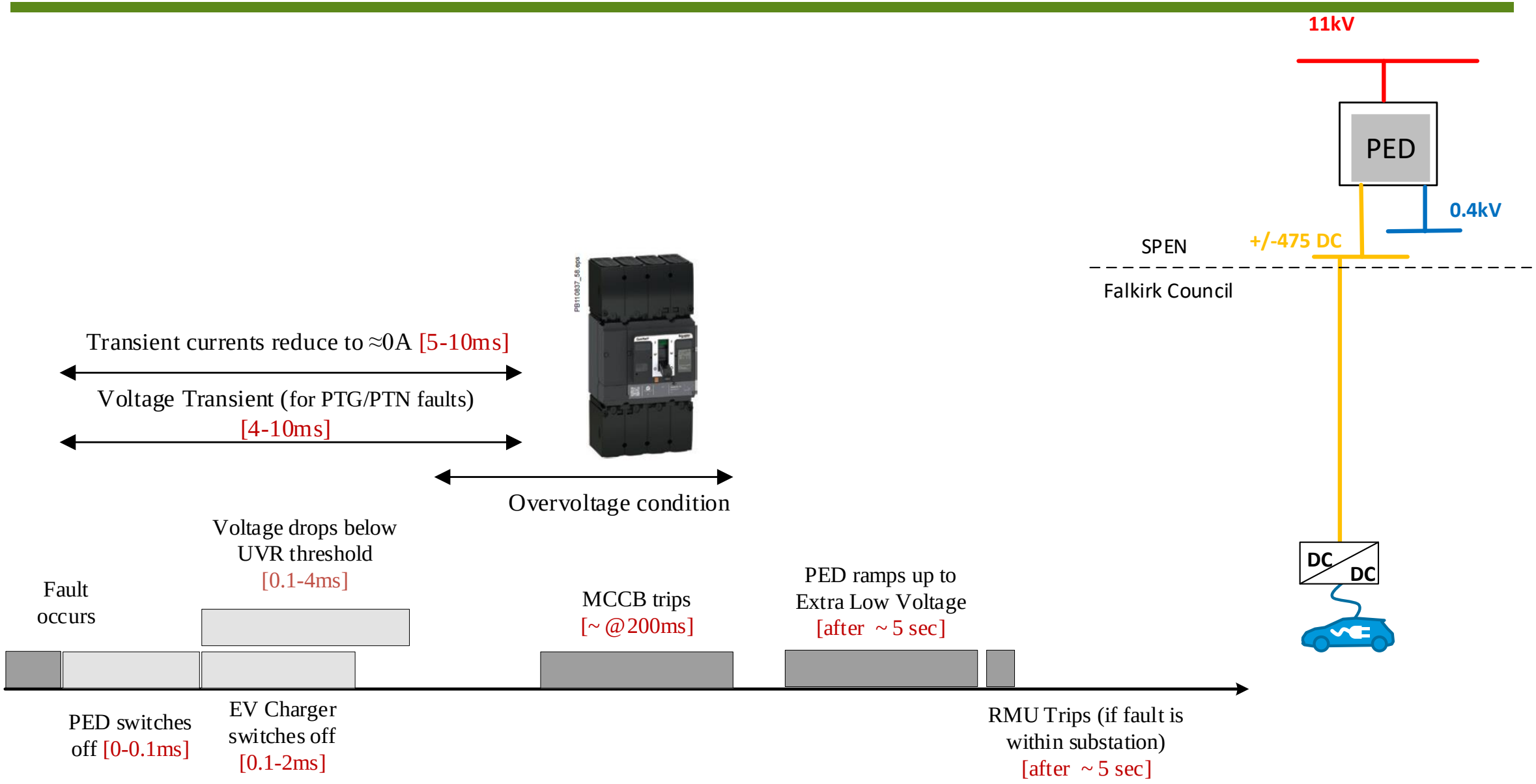






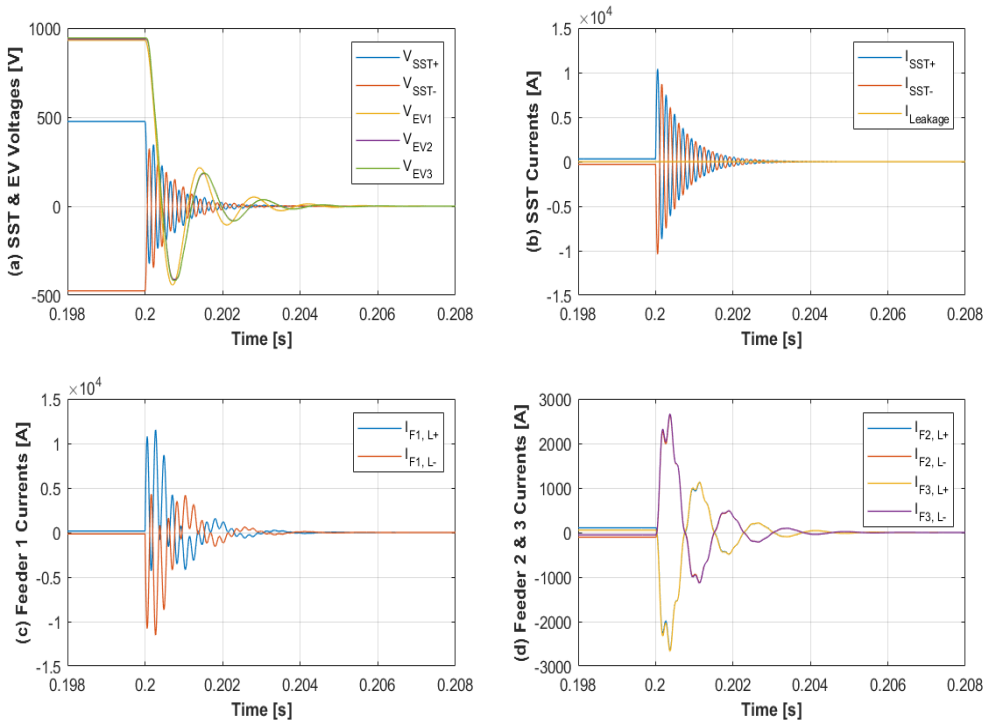


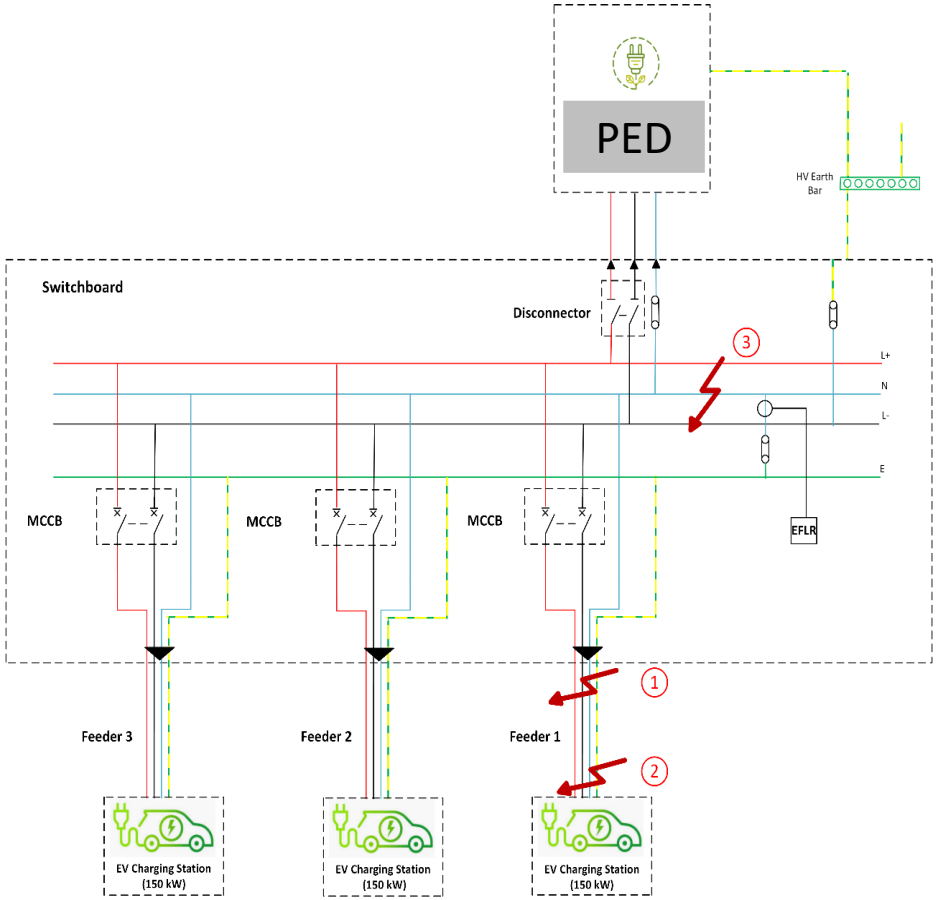
Protection strategy



Protection strategy next step

- Undervoltage protection is no longer application if there is multiple feeder
- Relying on overcurrent protection can be expensive and also results in a large size power electronics
- Smarter protection strategy should be adapted to detect/disconnect the faulty feeder but supply to healthy feeders should not be disrupted





The proposed solution is to design a protection logic controller that can measure fast transient current, detect fault occurrence, identify the faulted feeder and trip the corresponding MCCB

What will happen next in LV Engine ?

INSTALLATION AND COMMISSIONING IS BEING PLANNED FOR THE THREE SITES UNTIL END OF 2024 Q1.

PERFORMANCE MONITORING, OPERATIONAL EXPERIENCE AND MORE DOCUMENTATIONS FOR BAU ADOPTION

MANUFACTURING ANOTHER UNIT (NEXT GENERATION) BASED ON THE LEARNINGS CAPTURE IN LIVE TRIAL

MORE DISSEMINATIONS AND SITE VISITS FOR STAKEHOLDERS

PROJECT REPLICATIONS AND BAU INTEGRATION