Electricity Distribution

Phase Switch System

Geoff Down
Jacob Lynch

nationalgrid

The area we serve

National Grid Electricity Distribution brings energy to life for over 8 million homes and businesses across the South West of England, South Wales, the West Midlands, and East Midlands.

Our 7,200-strong team ensures the safe and reliable supply of electricity for an area of 55,500 km² stretching from the Isles of Scilly to Cardiff to Lincolnshire.

Our network of overhead lines, underground cables, and substations transforms power from the 400,000 volts supplied by National Grid Electricity Transmission to the 230 volts which provides essential power to homes and businesses.

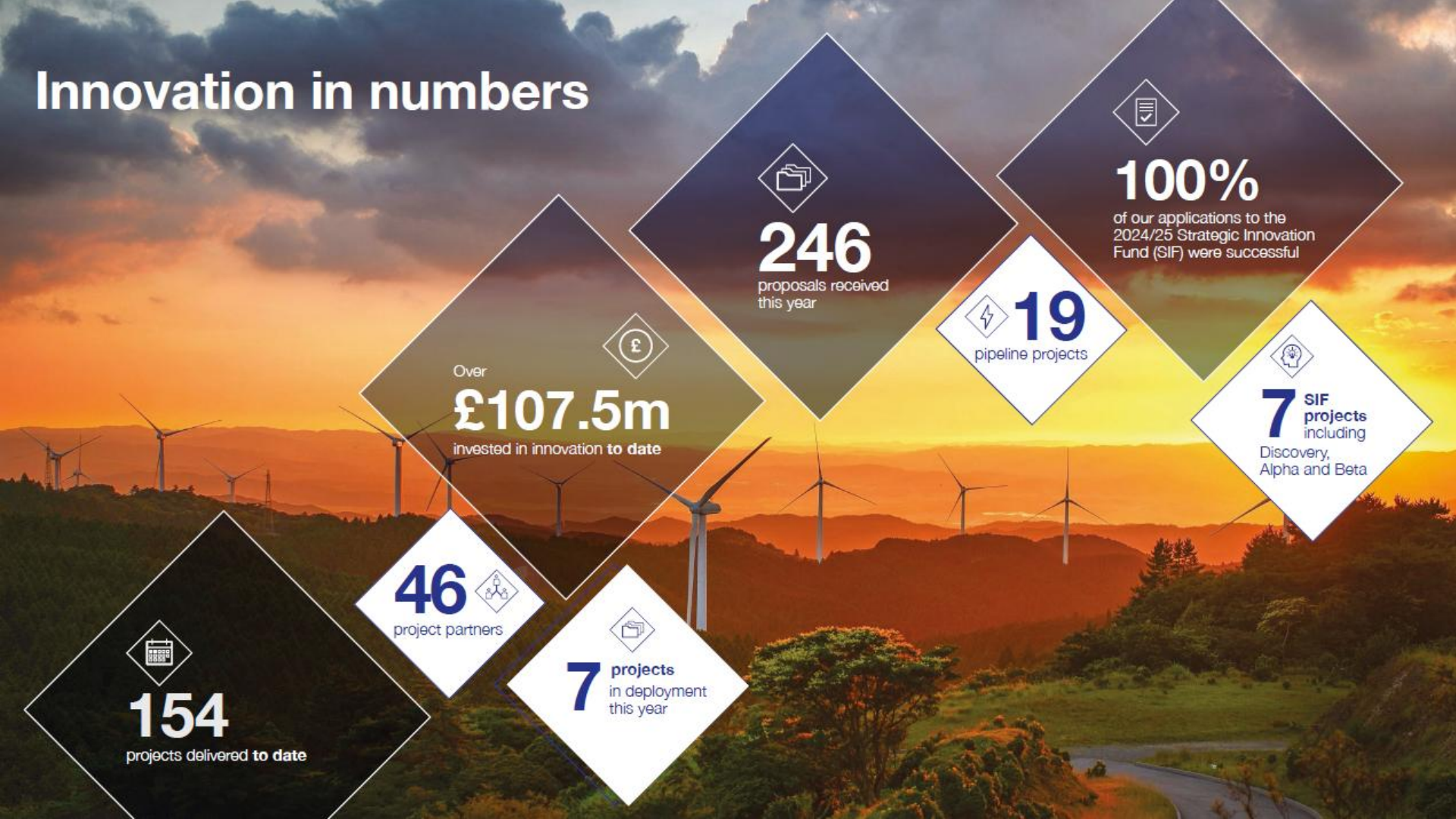
Innovation at National Grid Electricity Distribution is so much more than a team – it is a truly global ecosystem that brings together the experience and advances across various functions, industry partners, and innovative start-ups.

Our global innovation approach is aligned to our six key themes, ensuring that we use innovation to truly deliver the networks of the future in a way that allows all customers to be part of the transition, and unlocks advances in safety and network efficiency.

As well as working across our group portfolio, we engage with a range of partners including universities, other network companies, and start-ups - harnessing the power of collaboration, but also making sure advances and best practice are shared to the benefit of all customers.

This holistic approach not only addresses current challenges but also prepares us for future demands in the energy sector, and promotes efficiency and value by co-developing and sharing best practice.

Innovation in numbers




Smart Network Management
Understanding how we can invest and drive the network better
Safe and Efficient Operations
Improving our responses to faults, keeping people safe and working more efficiently
Faster Connections
Speeding up customer connections to our network
Our key themes
Our innovation projects sit under six different themes
Leveraging Data
Creating benefit with data insight
Supply Chain
Ensuring our supply chain is secure and provides value for money
Future Workforce
Retaining vital knowledge in our workforce while building up future skills

The challenge

LV networks are inherently unbalanced across the 3 phases

1. **Uneven load distribution.**
   - Single-phase loads (like residential homes or small businesses) may be disproportionately connected to one or two phases.
   - This is especially common in mixed-use areas where load planning hasn't been optimised.
2. **Poor Network Design or Reconfiguration**
   - Historical changes to the network (e.g., new connections, rerouting) may not have considered phase balancing.

The challenge

As customers adopt low carbon technologies, such as electric vehicles, heat pumps, solar generation and batteries. Phase imbalance as electricity demand increases will become more of an operational problem for networks.

- Voltage management within the 230V limits (+ 10% and - 6%)
- Thermal capacity limits

Different rates of change as customer groups transition – building adaptability, occupation, use and the socio-economic cost of transition.

Introducing the Phase Switch System

The Phase Switch System is an innovative solution to the emerging issue of increased and more variable phase imbalance across DNO LV networks due to the adoption of low carbon technologies by customers

- ✓ **Phase imbalance can currently only be addressed by manually reconfiguring customer connections or via network reinforcement**
- ✓ **PSS solution is a piece of street furniture**
- ✓ **Automatically balances load across the phases**
- ✓ **Reduces losses and the need for expensive reinforcement**

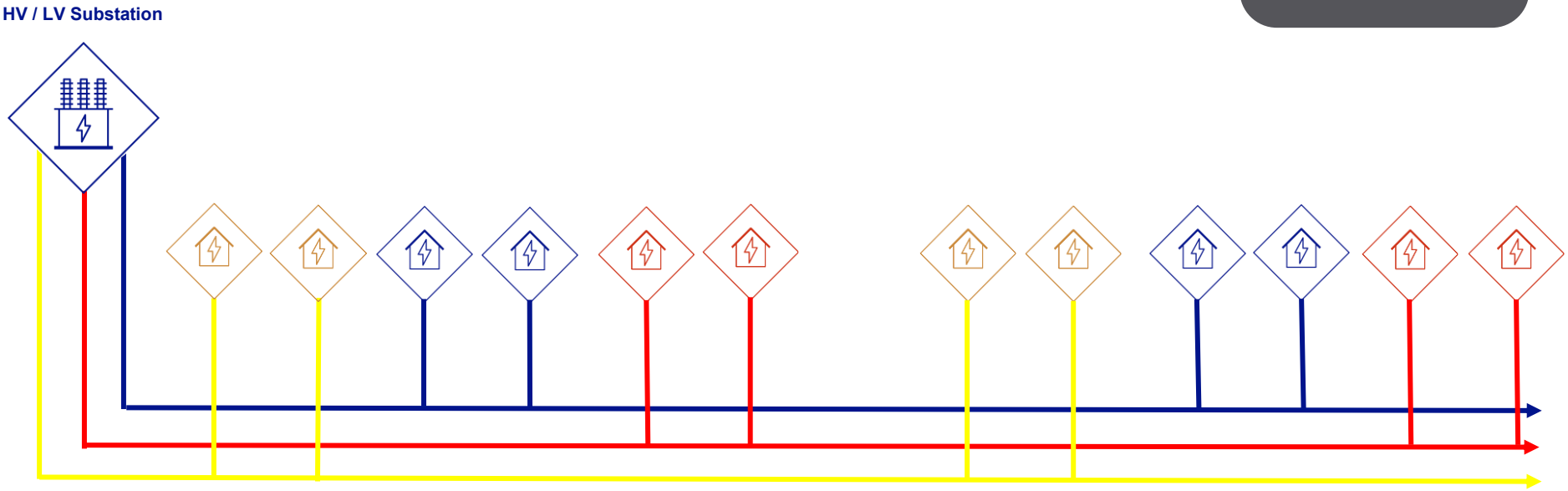
PSS prototype developed by Low Carbon Electric on the UKPN network (previous UKPN-led NIA project)

Low Carbon Electric

How does it work?

Balanced LV Network
Ideal

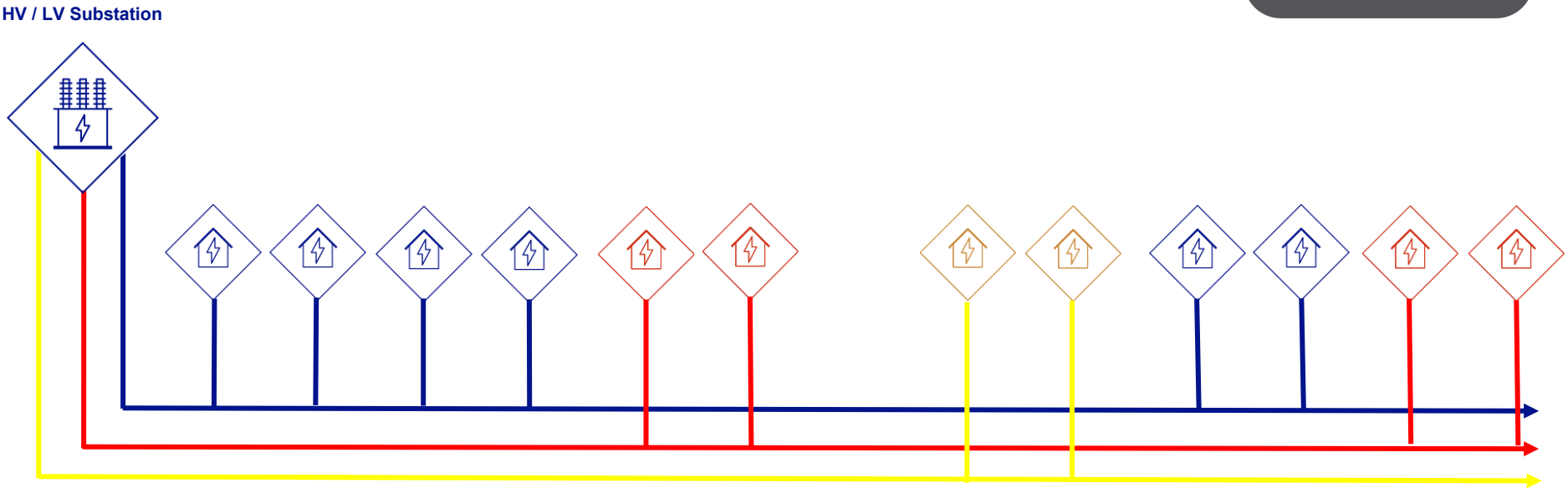
4 Houses L1
4 Houses L2
4 Houses L3



How does it work?

Balanced LV Network
Reality

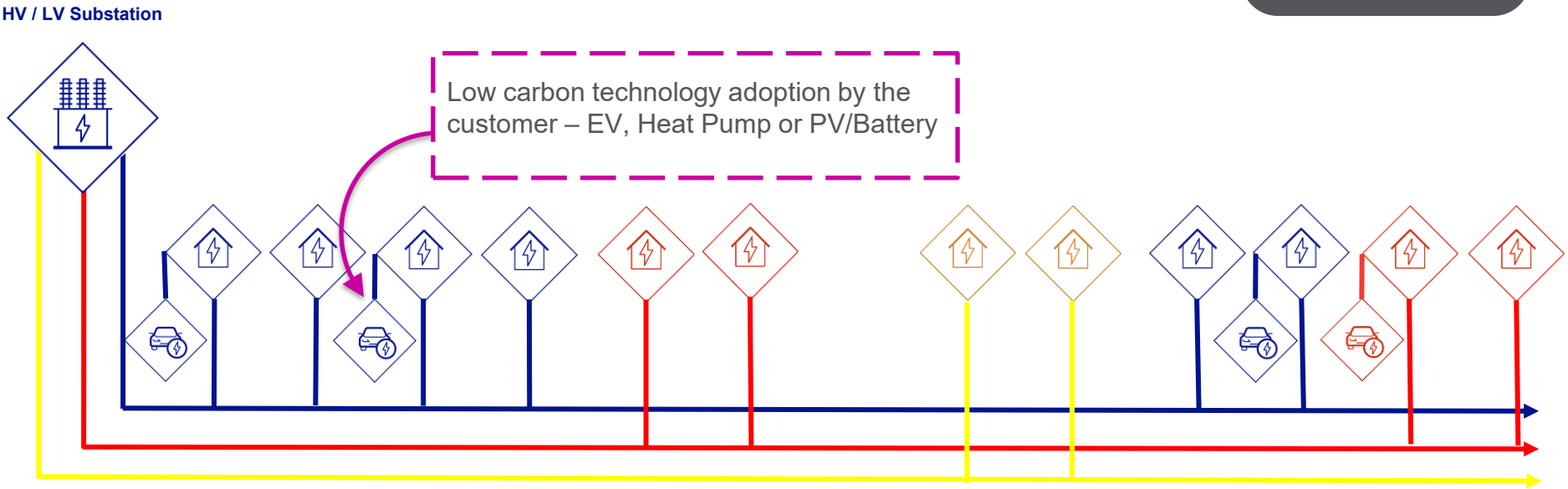
6 Houses L1
4 Houses L2
2 Houses L3



How does it work?

Balanced LV Network
Future

6 Houses L1
4 Houses L2
2 Houses L3

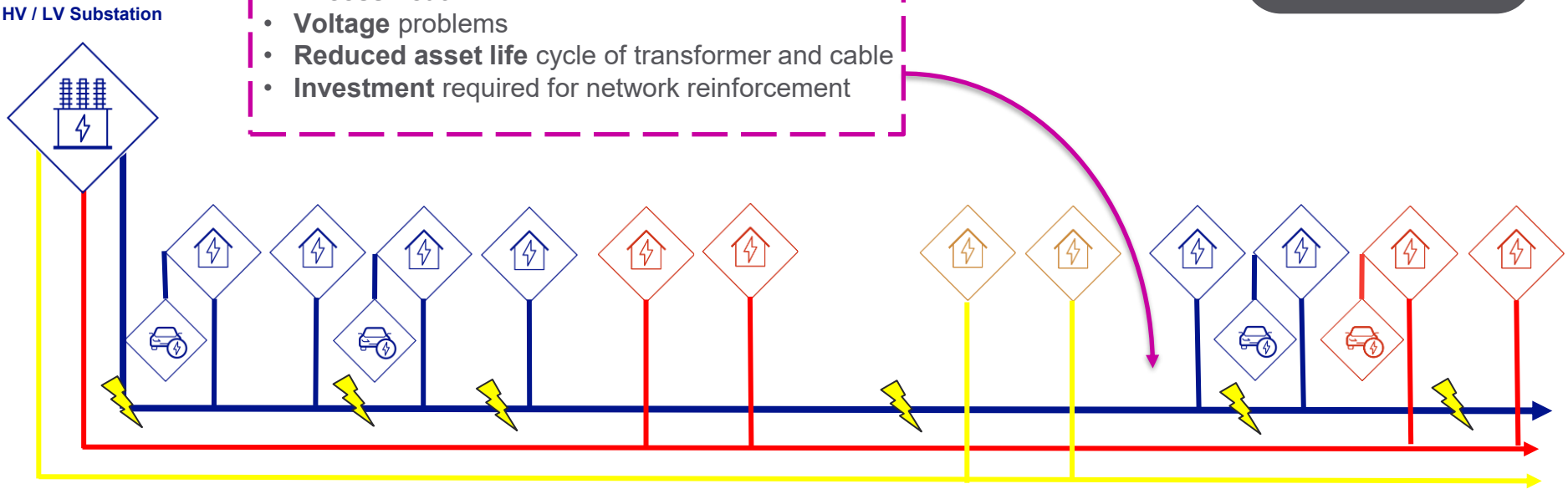


How does it work?

Balanced LV Network
Future

6 Houses L1
4 Houses L2
2 Houses L3

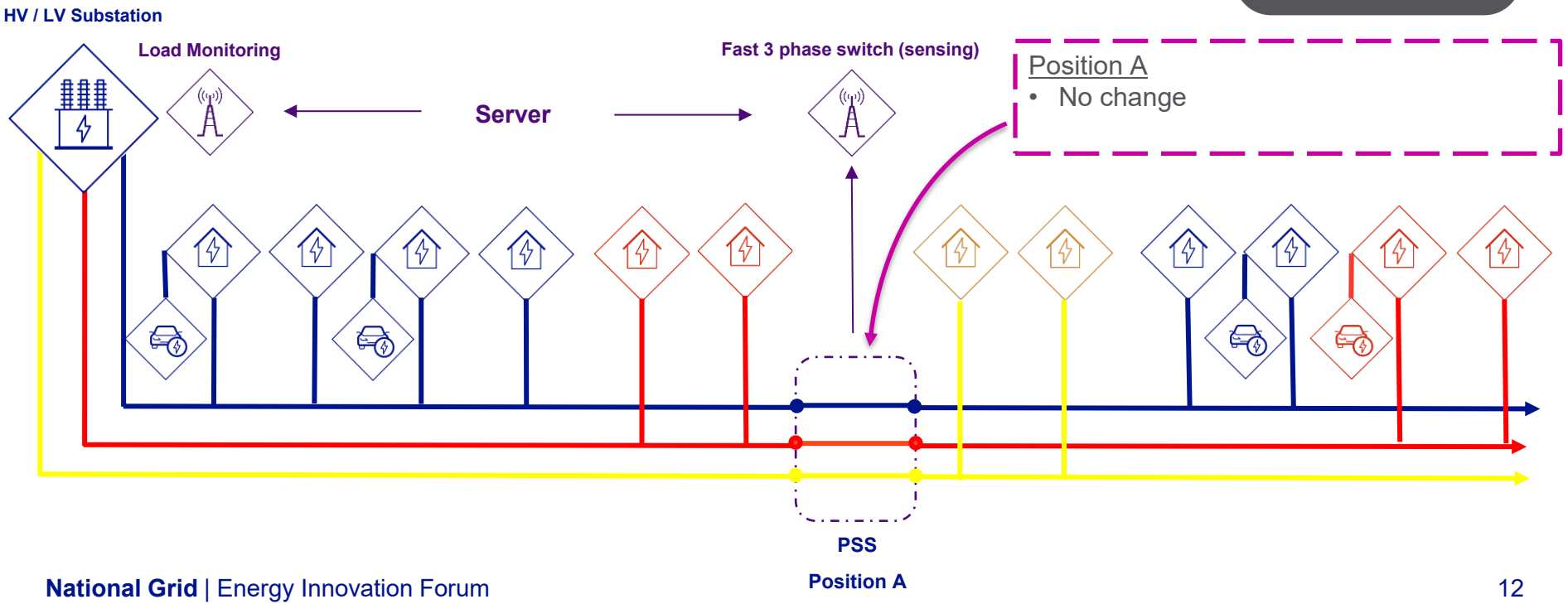
- **Excess heat** on L1 cable
- **Voltage** problems
- **Reduced asset life** cycle of transformer and cable
- **Investment** required for network reinforcement



How does it work?

Balanced LV Network
Phase Switch: Position A

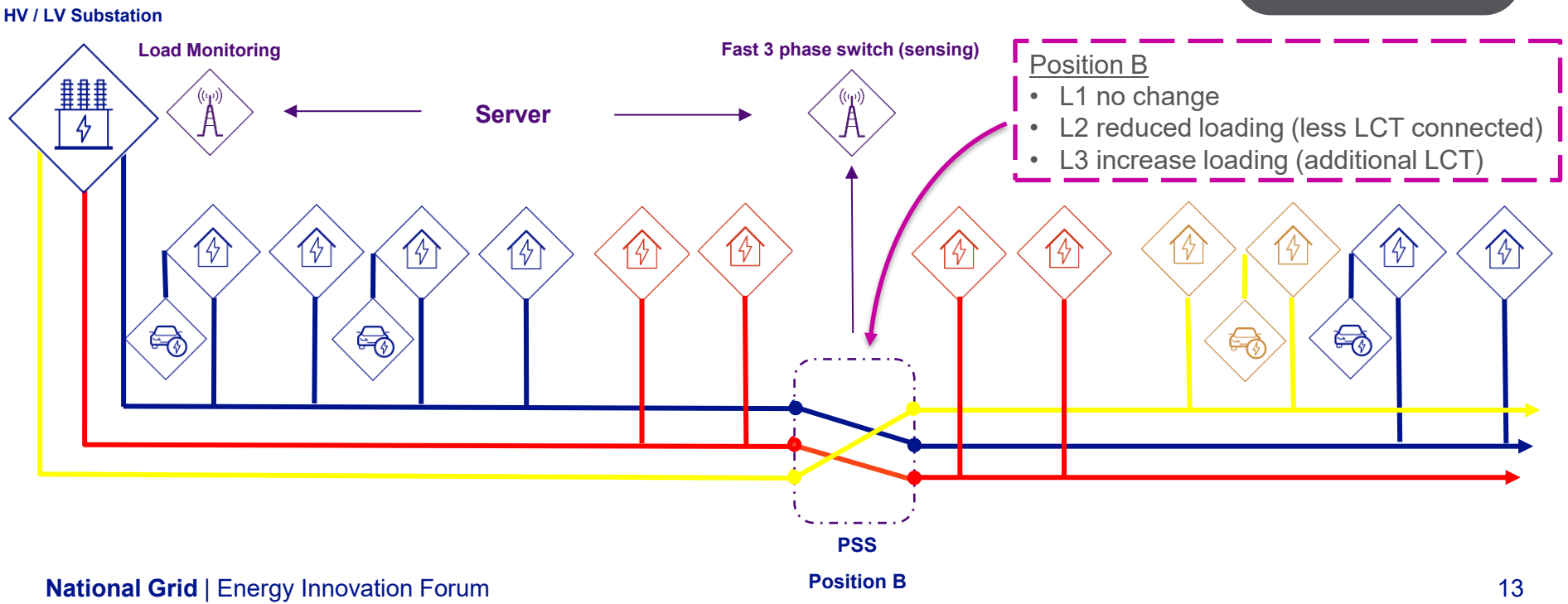
6 Houses L1
4 Houses L2
2 Houses L3



How does it work?

Balanced LV Network
Phase Switch: Position B

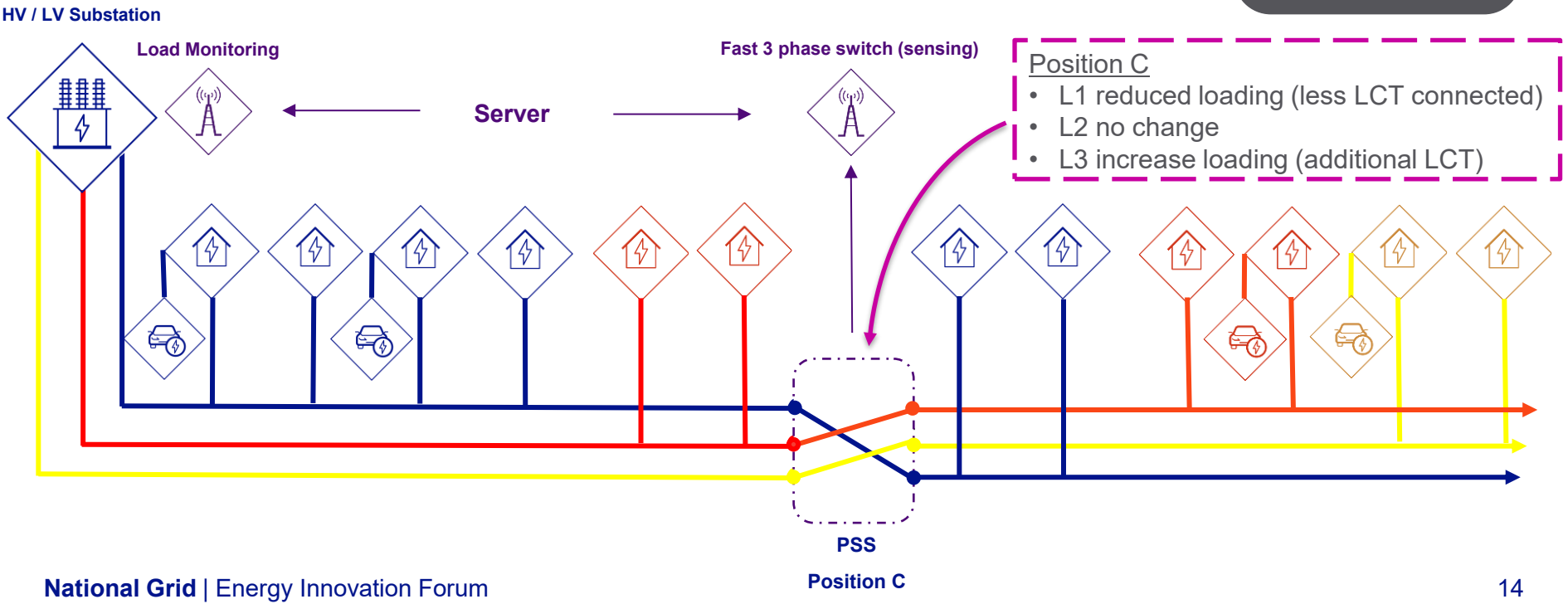
6 Houses L1
4 Houses L2
2 Houses L3



How does it work?

Balanced LV Network
Phase Switch: Position C

6 Houses L1
4 Houses L2
2 Houses L3



Programme of work

Phase 1 – Proof of Concept

Led by UK Power Networks

June 2019 – March 2023

Network Innovation Allowance

Worked with Low Carbon Electric to take the prototype from the laboratory to demonstrate that it could be connected to the LV network and work as designed.

- Demonstrated it was safe to connect to the LV network
- Tested at PNDC that it could move demand from one phase to another without noticeable impact (light flicker) to the customer.
- Tested at PNDC that a fault could pass through and not be transferred to another phase.
- Produce installation and maintenance instructions

Phase 2 - Demonstration

Led by NGED

September 2024 – January 2028

Strategic Innovation Fund

Further develop and tests the Phase 1 existing protype to market readiness while providing a support tool for planning and optimisation of deployment.

- PSS Solution Technical Development and Testing
- Planning Tool Development
- Network Trials
- Post Trial Evaluation and BaU Proposal

Phase 2 - Partners

nationalgrid

Project Lead

Low Carbon Electric

Phase Switch System Product

UK Power Networks

Project Partner

Phase Switch System

SIF Beta Project

September 2024 – January 2028

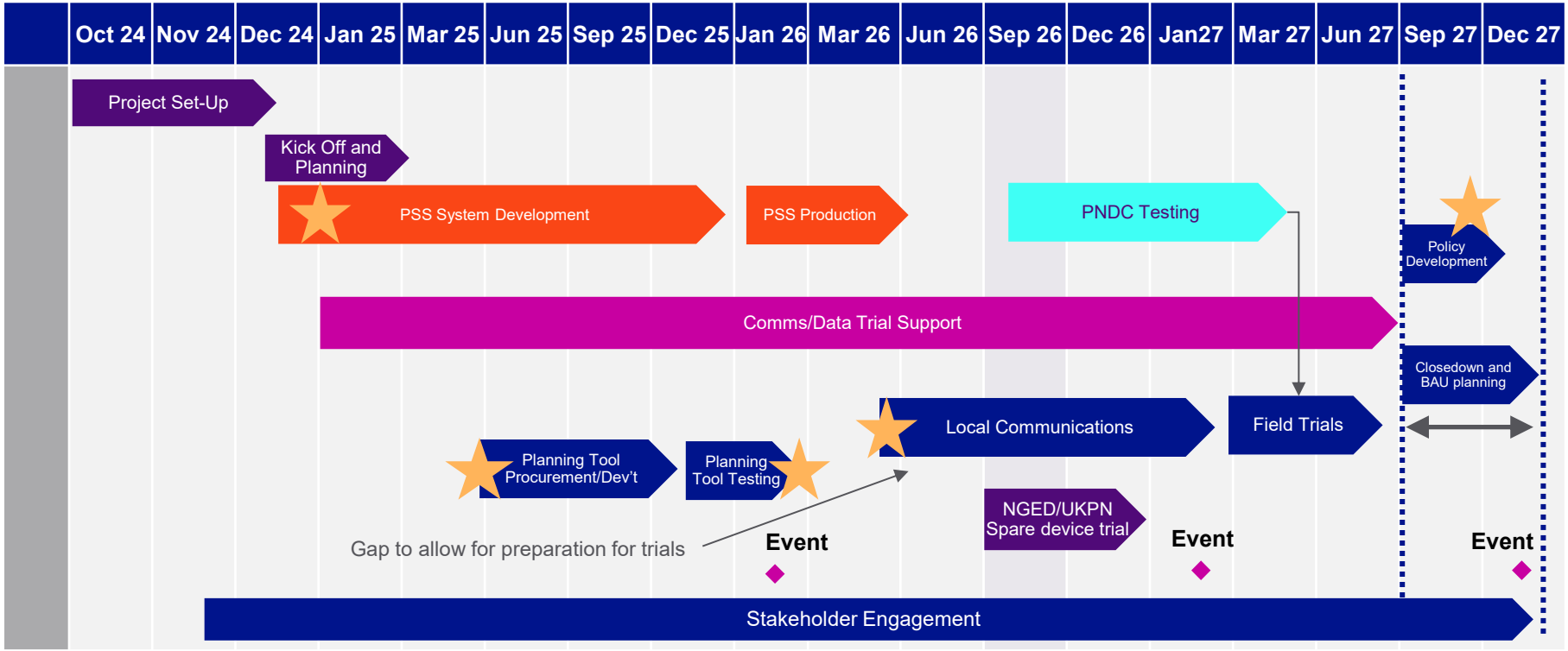
nortech

Comms and Data Management

UNIVERSITY of STRATHCLYDE PNDC

Testing

Phase 2 – Demonstration Timeline



How we will test the PSS solution

The PSS trials will focus on three key outcomes and deliverables

Lab Tests

Field Trials

- Proving the technology in the field and any impacts on customers
- Proving the investment case/benefits
  - EV charging hosting capacity validation
  - Total losses (including transformers)
  - Voltage
- Creating the case and policies for change

How we optimise installations

Field Trials

- **Build a Network Planning Tool** – optimise test locations
  - **Predict benefits** based on existing measurements/estimated demand profiles
  - **Predict benefits** based on forecast future demand profiles that reflect the expected deployment of LCTs which will increase network imbalance
  - **Include a spatial check** to determine issues with narrow paths and suggest best locations for installation
- Will allow the installation programme to select the **best value for money installations**
- Will allow the installation programme to be **efficient with dedicated teams**

Benefits

Operational

- Defer reinforcement where load is imbalanced allowing for more efficient reinforcement work
- Reduced need to attend fuse op's
- Improved voltage management (expected)
- Reduced CIs and CMLs

Environmental

- Reduced losses and associated CO2 emissions
- Reduced Fuse Op visits

Customer

- Easier to adopt LCTs
- Reduced CIs and CMLs
- Lower bills (Deferred reinforcement and reduced losses)
- Fairer access to providing flexibility services due to better voltage management

PHASE BALANCING TO INCREASE LV NETWORK HEADROOM: PHASE SWITCH SYSTEM TRIAL

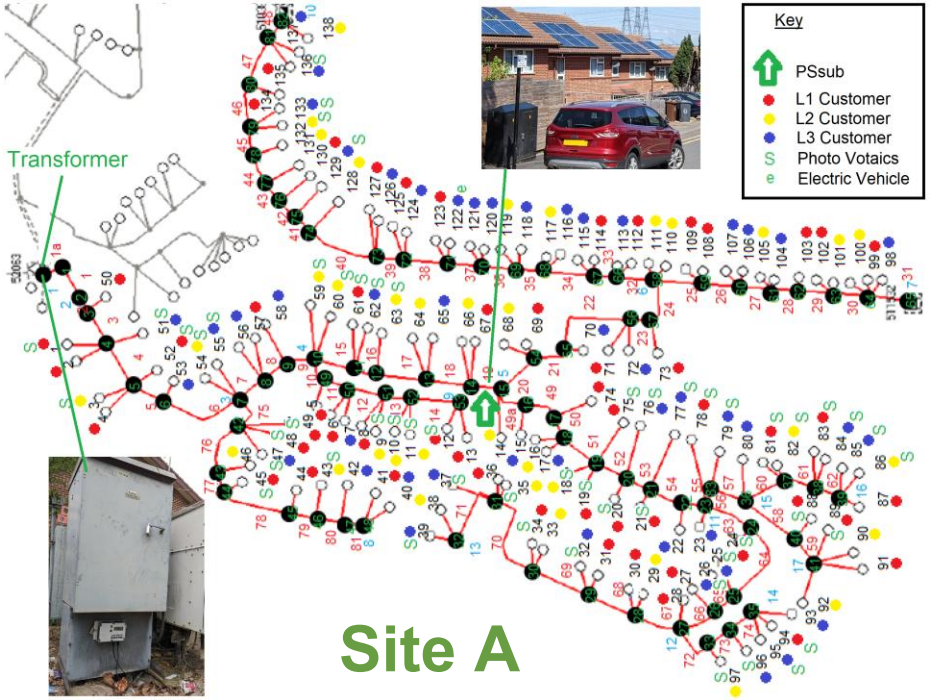
Martin CATON [1], Peter LANG [2], Peter CROSSLEY [3,1], Martin ADE-HALL [1]

[1]Low Carbon Electric Limited, Bolton, UK, [2]UK Power Networks (Operations) Limited, London, UK,
[3]Department of Electrical & Electronic Engineering, The University of Manchester, Manchester, UK,
martin@lowcarbonelectric.com, peter.lang@ukpowernetworks.co.uk, peter.crossley@manchester.ac.uk,
martinade-hall@lowcarbonelectric.com

Offline Analysis for Phase Balance Optimisation

Objective: Switch only for significant phase balance improvements to prevent 'hunting'

CIRED 2024 Vienna



PSS's installed and set to PSS-Off mode, monitoring only with no phase switching.

Data analysis on Site A to determine optimal phase switching frequency settings for PSS-On mode.

Phase connections from UKPN plans; not independently verified.

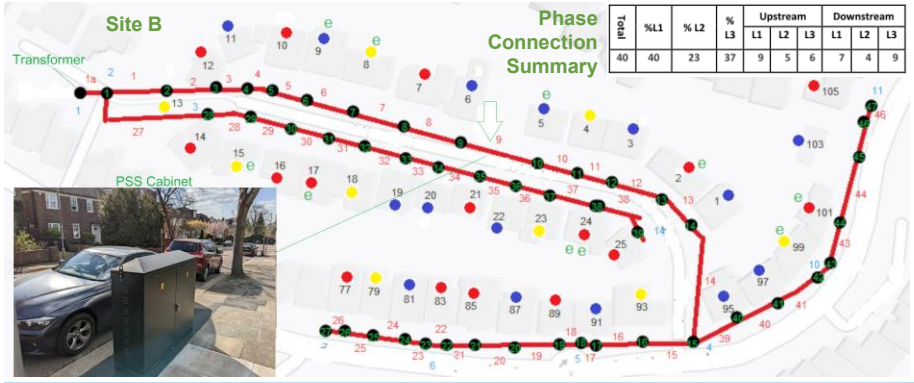
Estimated LV-main neutral current for each PSS switch position (5 min rms intervals).

Tested threshold values (TV); exceeding TV triggers phase switch, setting frequency.

Switching Profiles

Trial Results Site B - PSS Off Compared to PSS On

TV = 30A, Phase Switch is actuated when system detects it can reduce neutral current by more than TV



Total	%L1	% L2	% L3	Upstream			Downstream		
				L1	L2	L3	L1	L2	L3
40	40	23	37	9	5	6	7	4	9

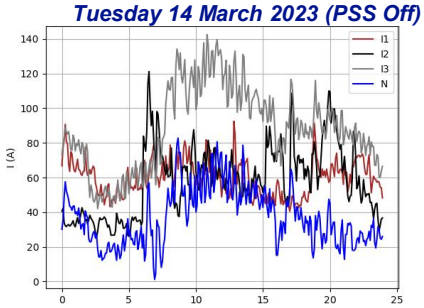
PSS Increase in Current Carrying HC March 2023

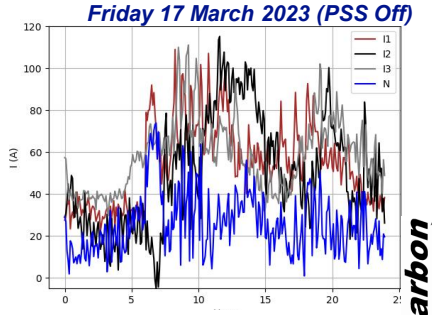
Peak	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
H_{off} (A)	275	209	259	225	208	140	95
H_{on} (A)	155	162	232	133	84	121	59
H_{est} (A)	187	131	119	194	63	136	89

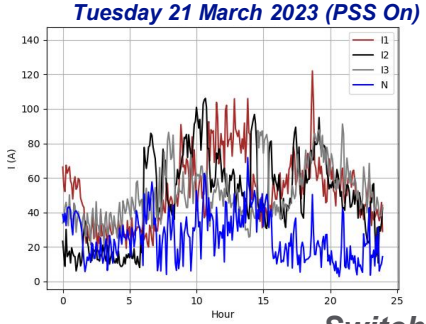
H_{off} is the increase in HC current at PSS Off peak time.

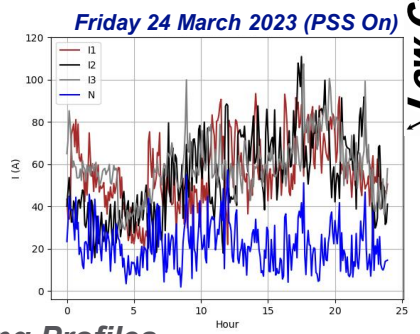
H_{on} is the increase in HC current at peak time for each day.

H_{est} is an estimated increase in HC current the PSS may achieve which uses only LV Monitor data.

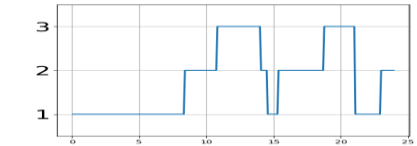


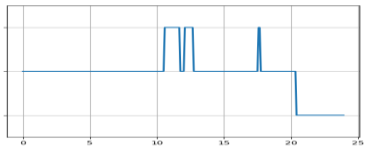






Switching Profiles



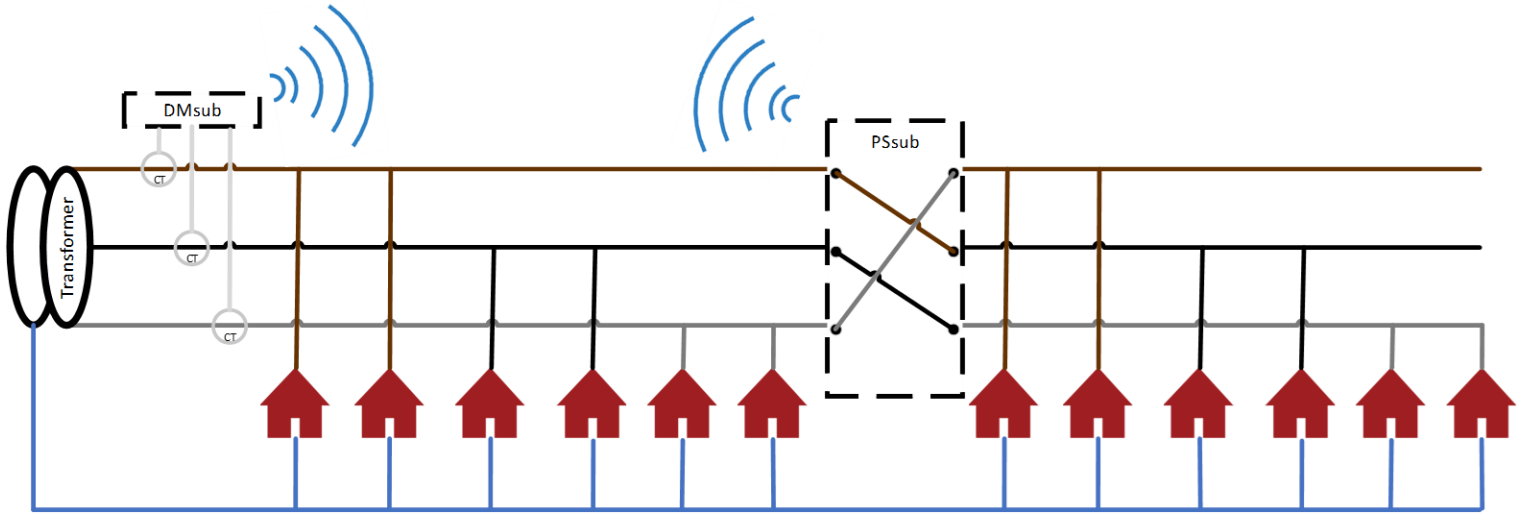


Low Carbon Electric

CIRED

Measured PSS LV-Main Losses

- Experiment dates: Feb 10, 2023, at 10:36 and Feb 17, 2023, at 16:39.
- Measured PSS's impact on LV-main losses.
- Power measurements taken quickly (less than 1 min) for each switch position (SP) to ensure consistent load.
- Compared sum of phase powers for each switch position.
- Results from the two experiments: SP B and SP C respectively had 3.2kW lower losses than SP A (no PSS).
- Potential annual loss reduction: 28MWh on Site B LV-main.



National Grid

CIRED 2024 Vienna

Low Carbon Electric

Conclusions

M. CATON, P. LANG, P. CROSSLEY, and M. ADE-HALL, 'Phase Balancing To Increase LV Network Headroom: Phase Switch System Trial', CIRED Vienna Workshop, *Jun. 2024.*

Compared to Cable Overlay (CO):

- **PSS is significantly cheaper**
- **PSS requires minimal excavation vs. half the street dug up**
- **PSS is faster to install (time) and requires a smaller workforce**
- **PSS reduces losses in cables AND transformers**
- **PSS complements cable overlay by balancing transformer**
- **Avoids 'locked hosting' capability on CO**
- **Trial Results:**
  - 3.2 kW instantaneous loss reduction (28 MWh annual savings).
  - With 2023 annual load, 202A LV-Main average hosting capacity increase (max 232A).

Q&A

Reach out to the project team here:

Email: *nged.innovation@nationalgrid.co.uk*

Website*:* *www.nationalgrid.co.uk/innovation*

Sign up to our innovation mailing list to hear more about the progress on the PSS project via our monthly newsletter - including upcoming events.

SCAN ME