Electricity Distribution

V2G Dynamic Headroom Control

NGED and Loughborough University

January 2026

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Welcome

Housekeeping and Agenda

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02	**Background**	NGED
03	**Methodology**	Loughborough University
04	**Learning and Findings**	Loughborough University
05	**Next Steps**	NGED

For the main part of the session, please keep cameras and microphones off. At the end of the webinar, there will be time for questions.

Ask any questions in the chat or Q&A.

Slides and recording will be made available following the session.

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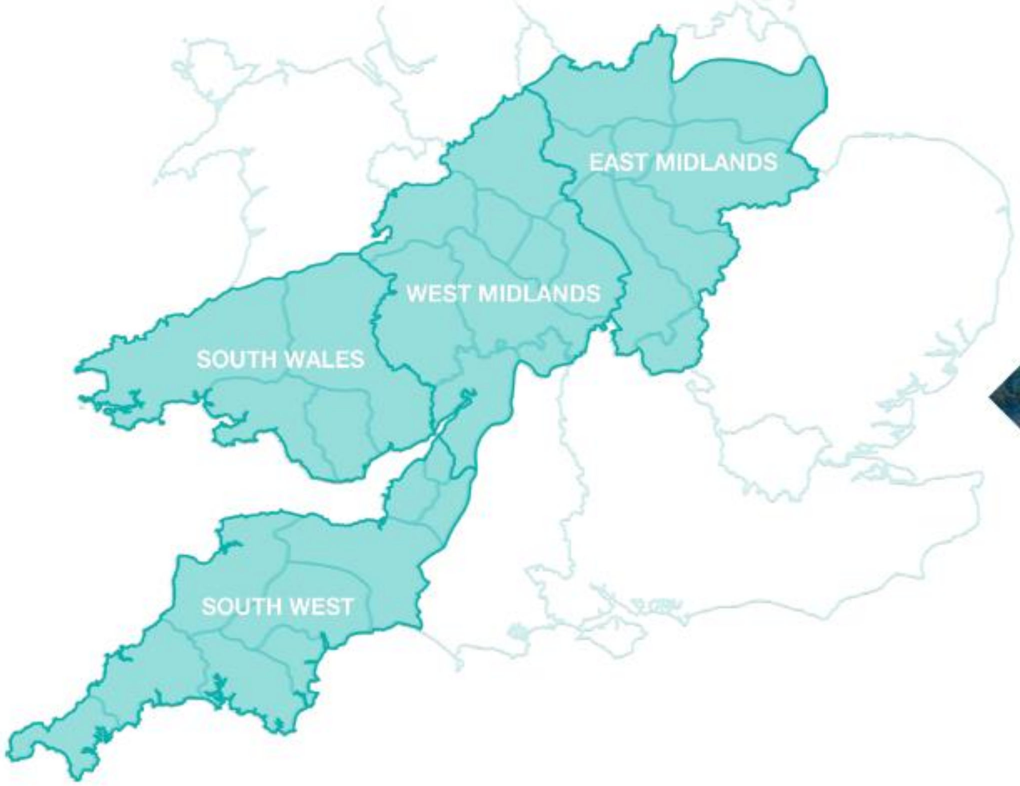
The area we serve

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 km^2 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

246
proposals received this year

100%
of our applications to the 2024/25 Strategic Innovation Fund (SIF) were successful

19
pipeline projects

Over
£107.5m
invested in innovation **to date**

7 **SIF projects** including Discovery, Alpha and Beta

46
project partners

7 **projects** in deployment this year

154
projects delivered **to date**

Our key themes

Our innovation projects sit under six different themes

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

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

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Background

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Background

- **V2G Dynamic Headroom Control** originates from the ENA Basecamp problem statement EIP046 presented in 2024
- **NESO Future Energy Scenarios for 2050** (Holistic Transition) suggests 81 GW of V2G capacity, equivalent to 22 million EVs, or around 76% of households
- This can be expected to cause **excessive voltage rise and thermal overloads**
- Control of V2G active and reactive power could **help manage these challenges**

Background

V2G Dynamic Headroom Control is funded via Network Innovation Allowance (NIA_076) and is delivered in collaboration with Loughborough University

Using smart meter and NGED network data, simulation models have been created to:

- Quantify existing capacity headroom along the length of selected LV feeders
- Predict the impact of projected V2G uptake, detailed by exact location
- Assess the effectiveness of V2G control for keeping voltages within range and operating within thermal limits – including control of V2G active export power, and reactive import and export
- Assess fairness of constraints applied to customers at different locations
- Quantify benefits of more targeted control where parameters are set locally and updated periodically

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Methodology

V2G Adoption

Loughborough University

- NESO Future Energy Scenario shows 81 GW of V2G
- At 3.7 kW export capacity, 76% of households
- DFES 2035 suggests around 80% uptake of EVs, so we assume all EV charge points eventually support V2G
- Assume, as a worst-case, that all V2G customers on a feeder could be coordinated and export simultaneously
- V2G installations may be locally clustered
- This represents a use of V2G for grid balancing support, where exports can occur at any time, when other demands are low and existing solar exports are high
- We assume that conflicts with G98 and G99 standards, and voltage thresholds for Protective Earth and Neutral detection will be resolved
- This work applies equally to exports from domestic battery storage

Voltage-based Controls

Volt-var control

- Imports reactive power at high voltage
  Exports reactive power at low voltage
- Active power and reactive power remain within 7 kVA rated capacity

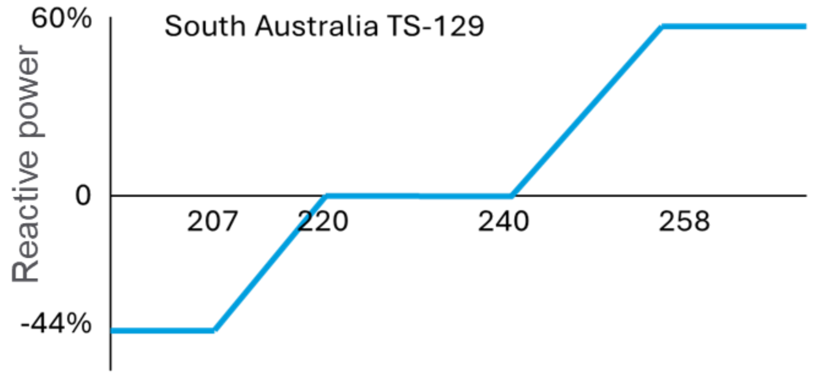
Volt-watt control

- Active power progressively reduced to zero as voltage increases from lower to upper threshold

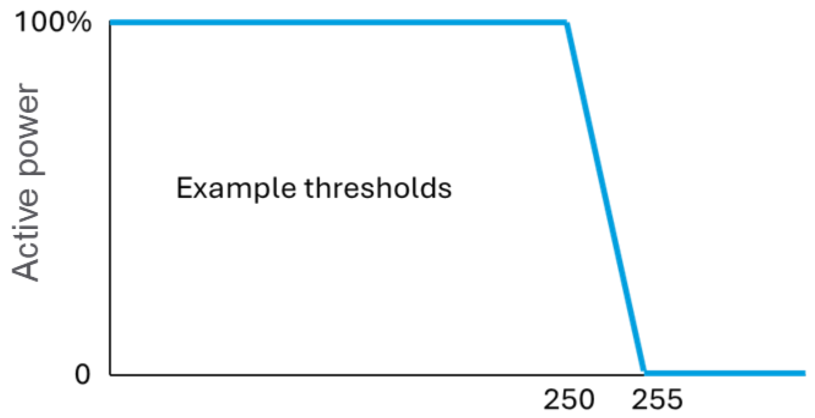
Volt-watt-var control

- Reactive power follows volt-var control
- Active power reduced based on volt-watt control

Volt-var reactive power response

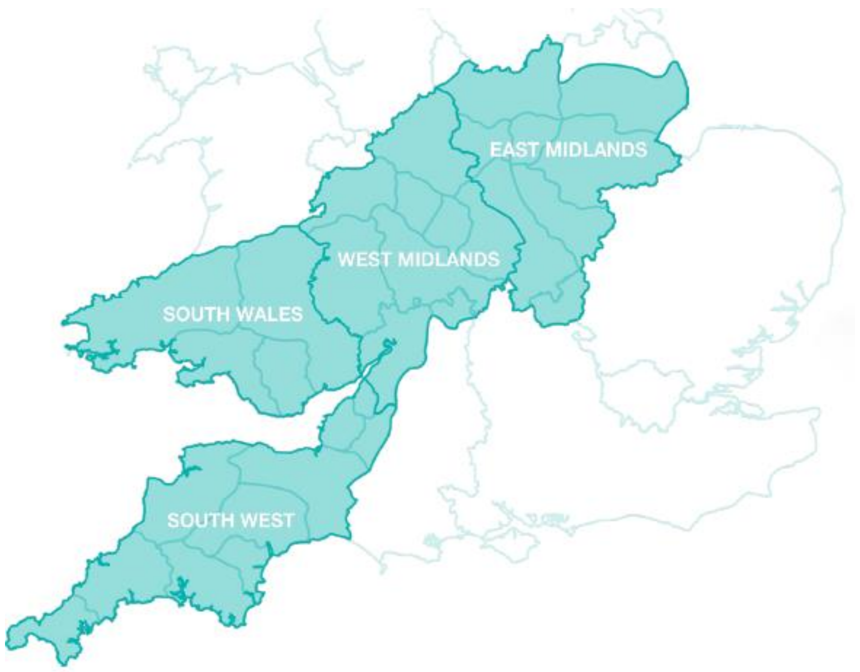


Volt-watt active power response



Site Selection

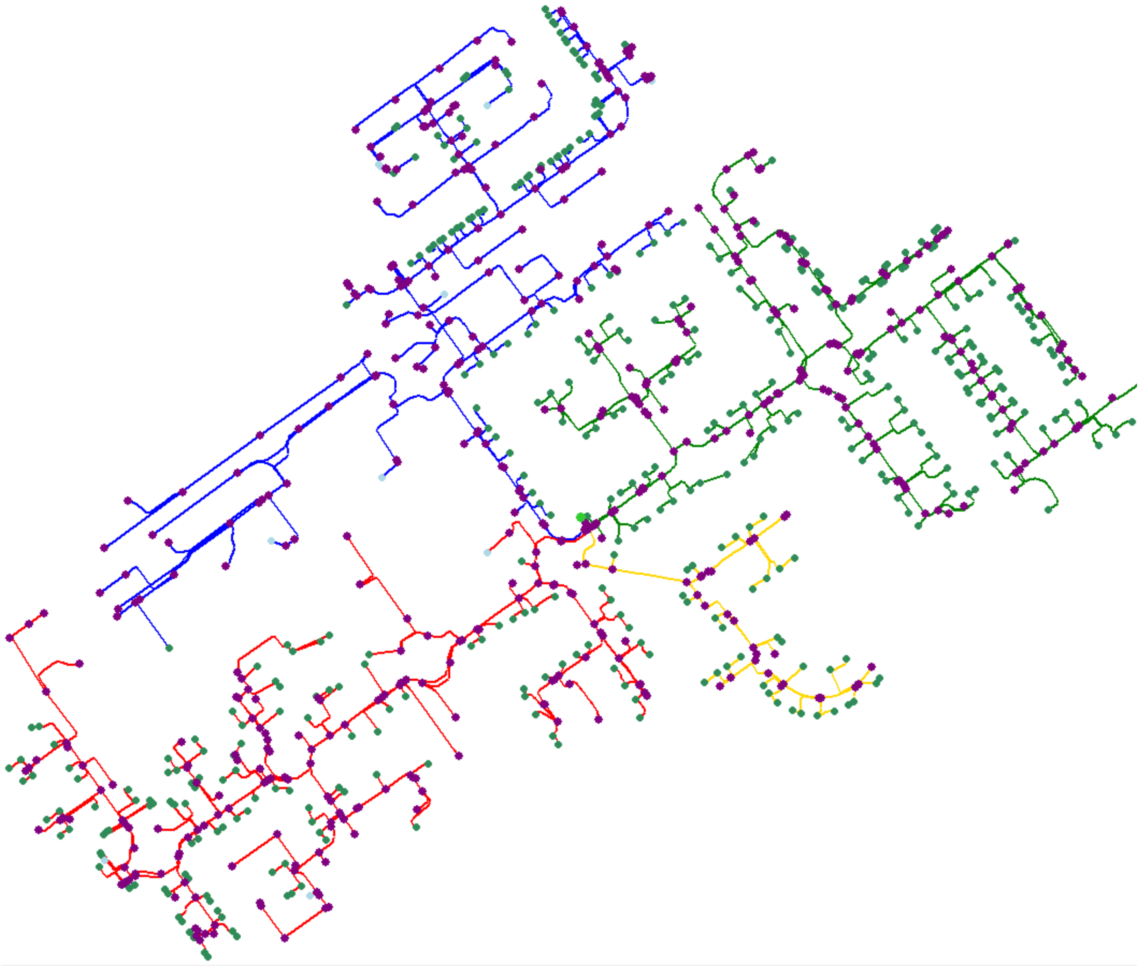
- Selected 86 distribution substations from across the four NGED license areas
- Selection prioritises substations with high adoption of smart meters, typically 80% uptake
- Inputs from NGED LV planning team to prioritise:
    - High LCT uptake and relative to transformer capacity
    - Long line lengths
- This tends to highlight smaller transformers, more likely pole-mounted and rural
- Biased selection – but a realistic representation of expected early concerns



Loughborough University Simulation Software

Loughborough University

- Bespoke Python-based LV power-flow
- Developed and validated against measurements in NGED Losses Investigation
- Forward/backward sweep method for unbalanced three-phase radial feeder analysis
- Imports NGED Electric Office network data
- Cables modelled with full 3 × 3 impedances
- Service cables added as required and phases identified using NGED SMITN project method
- Half-hourly time resolution to match smart meter demand data
- Flexibility to customise to project requirements



Super-position Headroom Model

- Smart meter data, voltage and demand, provides a baseline for the available headroom
- Voltage headroom – difference between upper voltage limit and the maximum voltage seen by any customer
- Thermal headroom – difference between maximum current and the cable rating (assumes operation up to full rating is viable)
  - Only known from smart meter demand for the first cable branch from the substation
  - This is mostly the bottleneck for cable utilisation
- Smart meter demand data is aggregated for customers on each feeder so individual demand data is not available
- To resolve this:
  - Establish a baseline impact of the existing demand using voltages from smart meters
  - Add differential voltage drops for modelled V2G
- Modelling calculates:
  - Voltage at each smart meter
  - Current in cables from the substation, combining modelled V2G and existing aggregated demand

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Learning and Findings

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V2G Exports Without Controls

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Voltage and thermal impacts from adding V2G

	Existing demand	With V2G exports
Probability of over-voltage	0.5%	43%
Probability of over-load	< 0.1%	13%

If V2G connects without management, many feeders exceed voltage and current limits

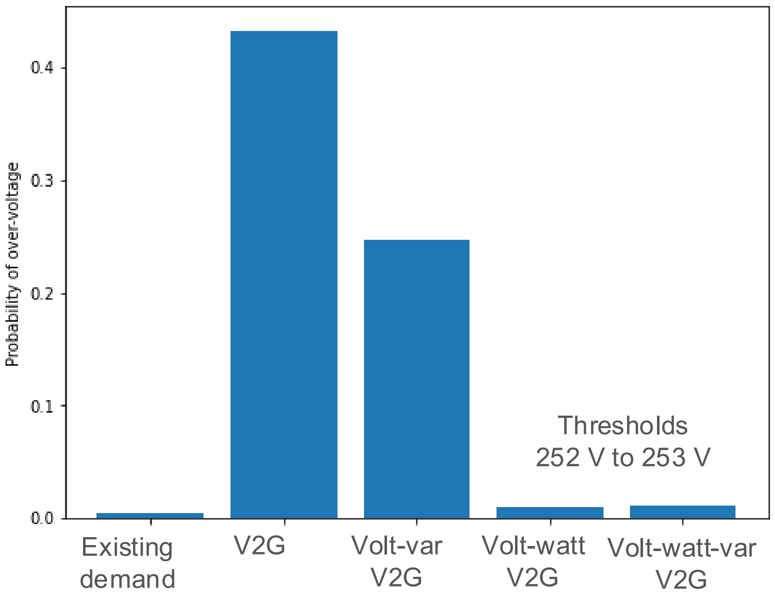
Constrained V2G within voltage and thermal limits

V2G customers	Mean export power
V2G unconstrained	3.7 kW
V2G constrained by voltage and thermal capacity	0.7 kW

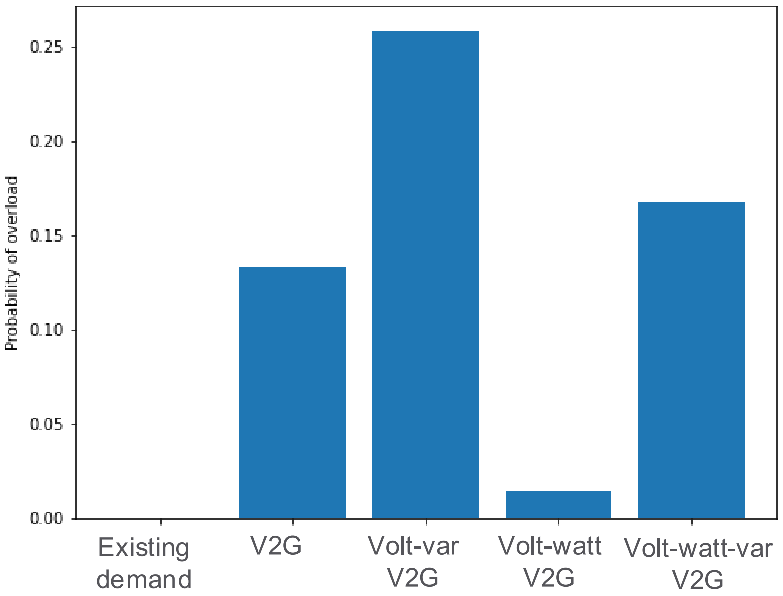
If V2G is constrained within existing capacity, most of the energy storage benefit will be lost

Voltage-based Controls

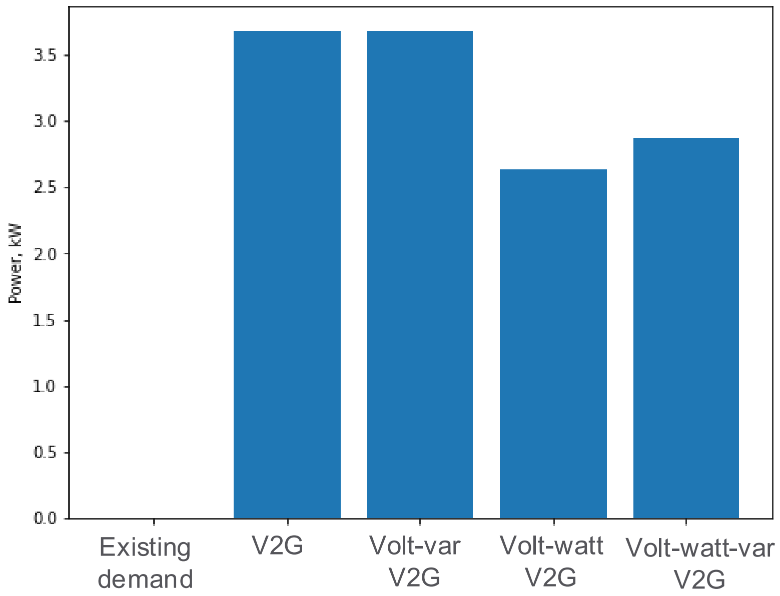
Probability of over-voltage



Probability of overload



Mean export power

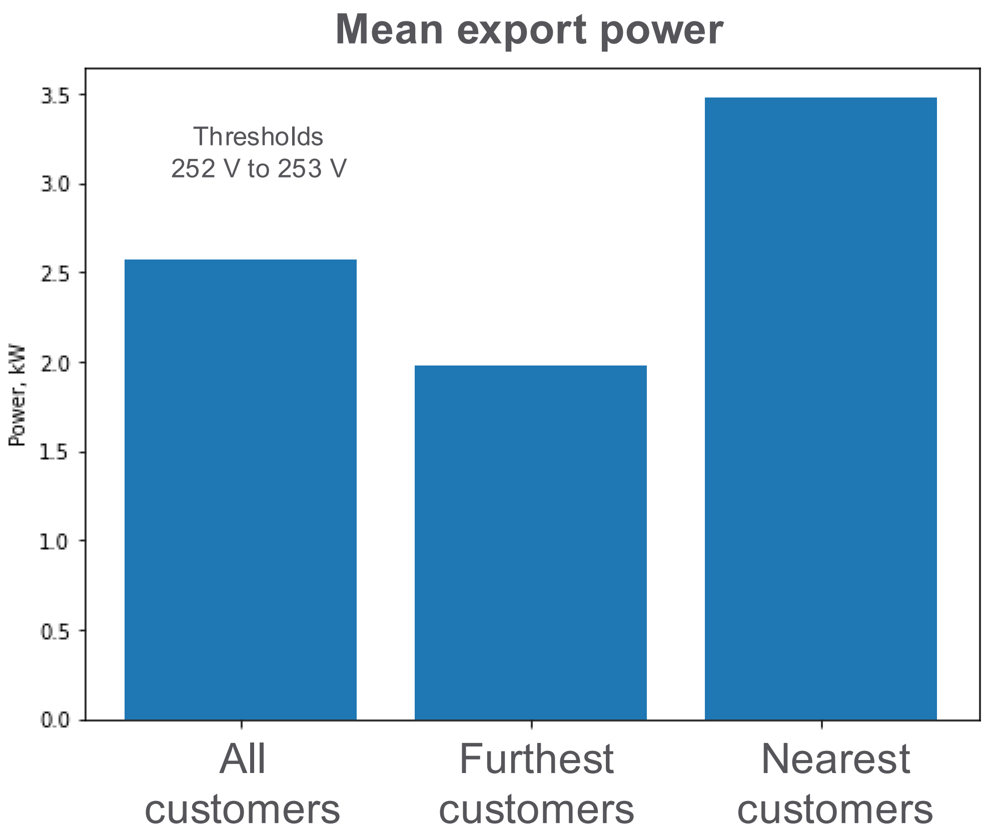


- Volt-var control partially reduces over-voltage, increases risk of overloads, but maintains the export power
- Volt-watt control solves the voltage and current issues, but reduces exports
- Combing both allows higher exports but with increased risk of current overloads

Voltage-based controls successfully maintain feeders within limits, but constrain exported power

Fairness for Exporting

- Customers at feeder ends are expected to be constrained more due to higher voltage rise
- This may be seen as unfair, and could affect ability to earn revenue from V2G exports
- Results confirm this effect
- Fairer approaches are possible, for example where all V2G devices respond to the maximum voltage anywhere on the feeder, but mean exports for all are reduced from 2.6 kW to 2.2 kW
- However, exports depend on the characteristics of each feeder, so unfairness between feeders still remains

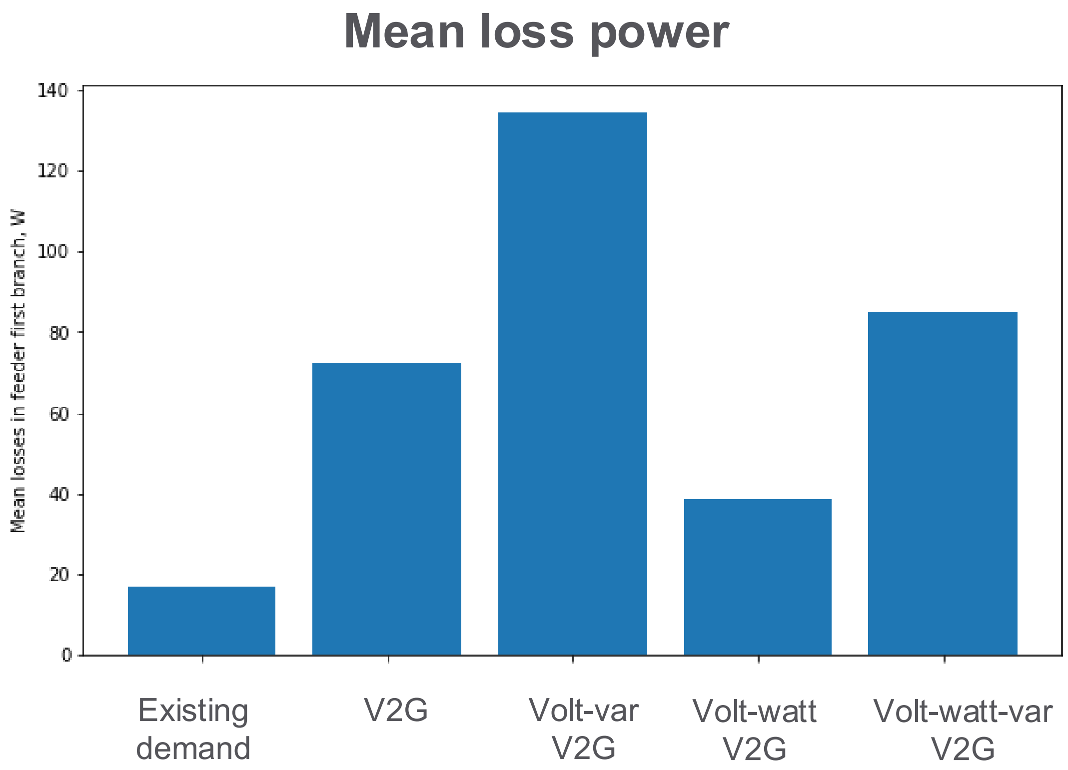


Export constraints are unfair within feeders

A fairer method is possible, but overall exports are reduced

Impact on Losses

- Modelling a case where V2G is active for 3 hours per day, all customers exporting
- Losses increase with V2G exports
- Volt-var and volt-watt-var control increase losses further due to reactive power flows
- Volt-watt control mitigates the increase in losses, but losses still increase as the feeder utilisation increases



V2G exports increase losses but provide a valuable energy storage facility

Volt-watt Control Thresholds

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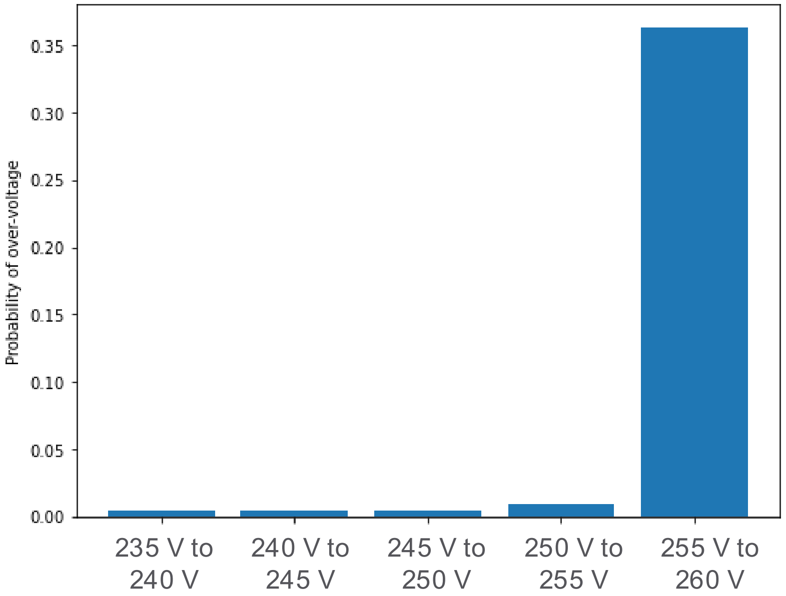
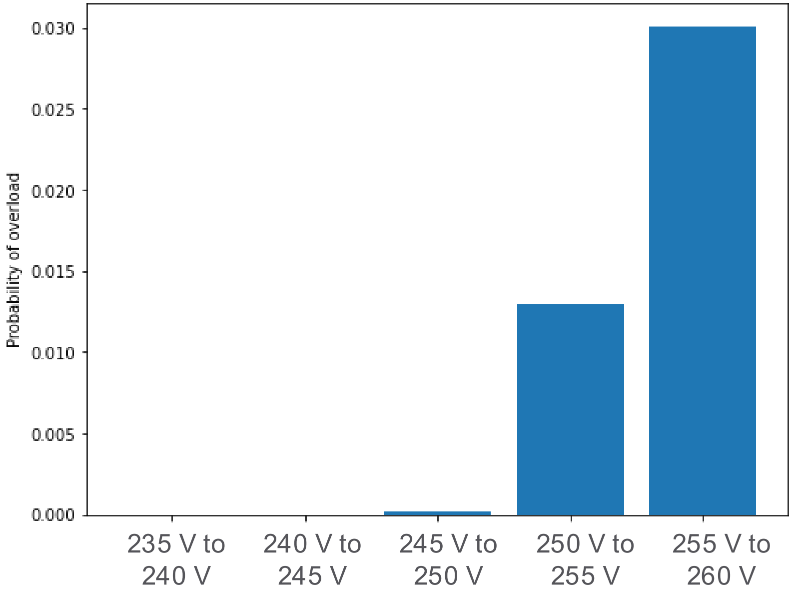
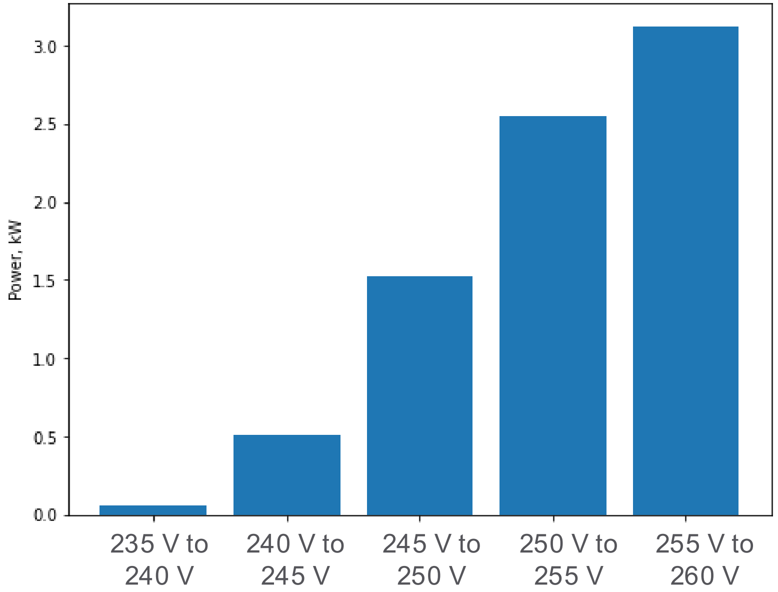
Probability of over-voltage



Probability of overload



Mean export power



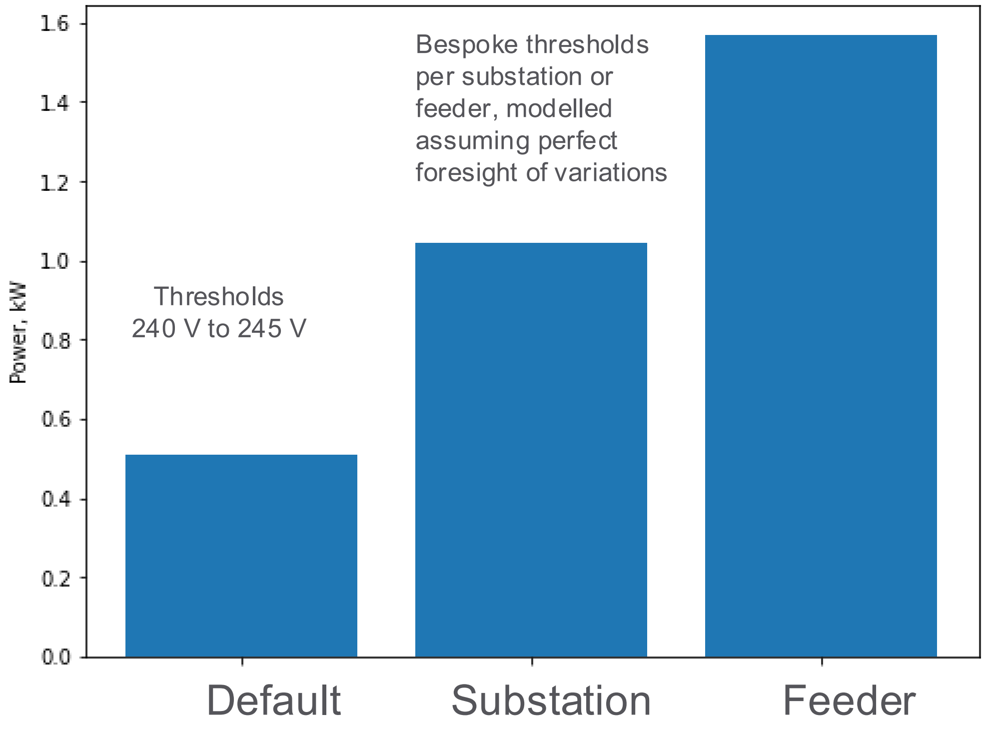
- Need for lower thresholds:
  - Existing voltage rise
  - Voltage-based control do not ensure thermal compliance
- Lower thresholds avoid over-voltages but reduce export power
- Full confidence of remaining within feeder capacity requires threshold lower than regulatory 253 V limit

Thresholds need to be lower than regulatory limit for some feeders

Dynamic Threshold Settings

- Volt-watt control thresholds could be customised for each substation, or each feeder, rather than using one preset factory default
- Customisation requires knowledge of the peak voltages and currents, from smart meter data
- Limits customised for each substation allow greater exports than with a preset default threshold, while respecting voltage and current limits
- Limits customized for each feeder allow a further increase in export power
- Practical implementation requires periodic communication with EV charge points to update thresholds as uptake of V2G or LCTs develops

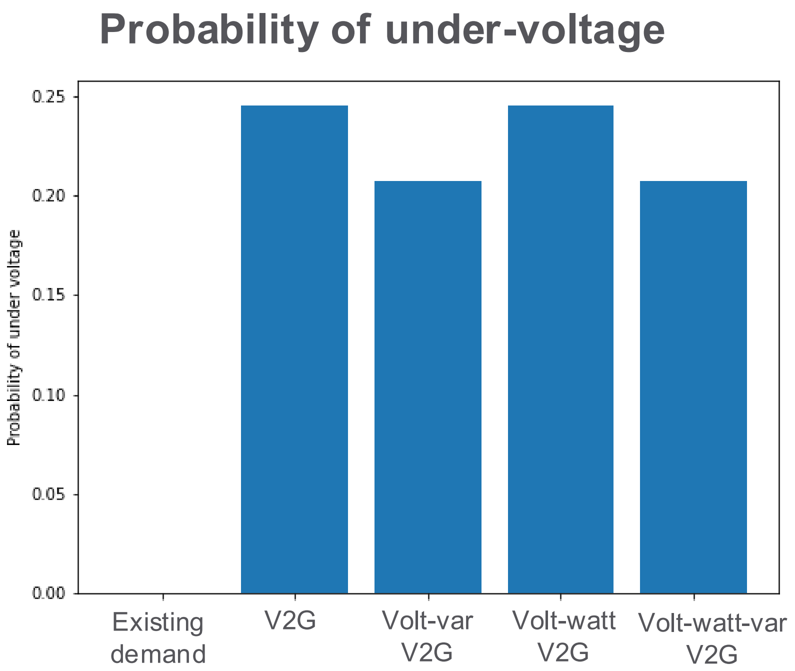
Mean export power

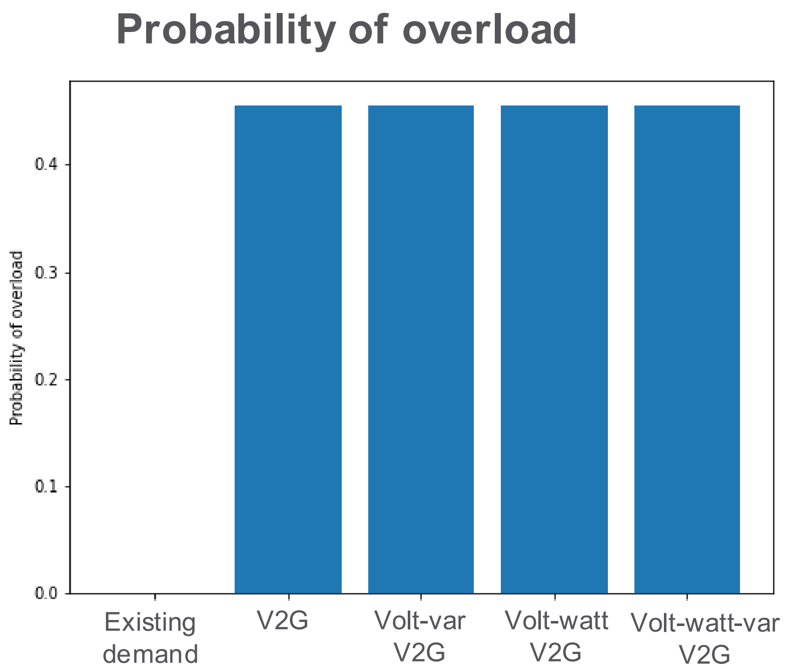


Dynamic updates to thresholds allow higher exported power, with confidence that this can be controlled if needed

V2G Recharging

- Importing after an export event could also be highly synchronised
- Import power is higher, rated 7 kW rather than permitted export of 3.7 kW
- Less easily regulated as this operates as normal EV charging





- Volt-var control mitigates the under-voltage problem, but not the current overloads
- Volt-watt control not included here at low voltages (though it could, if mandated for EV charging)

Voltage drop impacts of recharging could be more significant than voltage rise from exports – recharging needs temporal diversity, and maybe new standards

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Distribution Substation Tap Changes

Loughborough University

Could tap changes mitigate the V2G voltage rise problem?

Fixed tap changes

- Voltage range:
  Maximum customer voltage for exports, minus minimum customer voltage for imports
- If maximum voltage range over all time samples is less than the regulated voltage range, then resolving voltage issues with a tap change is hypothetically possible

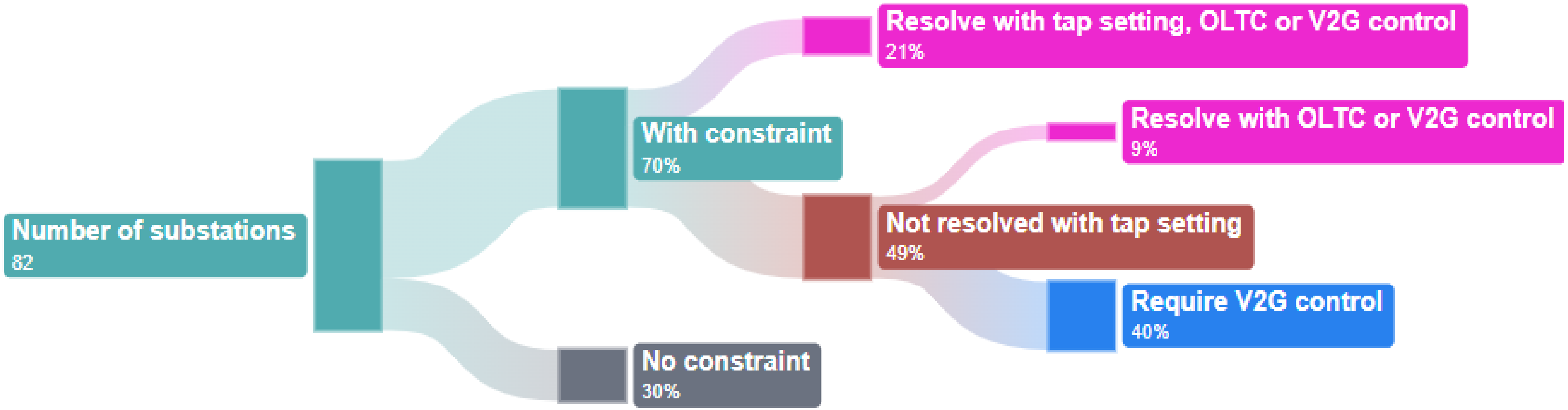
On-Load Tap Changers

- Voltage range calculated individually for each half-hour period
- If maximum half-hourly voltage range is less than the regulated voltage range, then resolving voltage issues with an on-load tap changer is hypothetically possible

Assumptions:

- Continuous rather than discrete tap steps, no margin for HV voltage variations, perfect foresight

V2G Voltage Management



Assuming future 230 V ±10% range, 207 V to 253 V

Around 40% of feeders eventually need V2G control or other interventions

Summary of Results

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- As V2G uptake develops, simultaneous exports cause **voltage and thermal limits to be exceeded**
- Refusing connections to ensure compliance will **lose the system benefit of V2G**
- **Volt-watt control** appears most promising, but **volt-var control** allows exports to be retained
- Constraining exports using voltage controls **successfully maintains feeders within limits**
- This provides a backstop but causes customers to lose revenue, so could be seen as a backstop while **other interventions are deployed**
- Our results have demonstrated where these constraints **can be unfair between customers**
- **Dynamic control allows greater mean exports** than with a preset factory default
- **Thresholds would be reduced**, where indicated by voltage and demand data from smart meters
- This **requires a communication path** for periodic updates, possibly via the supplier or aggregator

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Next Steps

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Next Steps

Evaluate the effectiveness of the same control techniques for other LCTs

Discuss and agree trial options

Disseminate further at industry events

Finalise closedown report and publish findings/learnings

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Q&A

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