WESTERN POWER DISTRIBUTION
NETWORK EQUILIBRIUM

Network Equilibrium

Voltage Limits Assessment Workshop

Birmingham, 6th October 2015

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SAFETY MOMENT

FIRE ALARMS, EXITS & MUSTER POINTS

WORKSHOP AGENDA & OBJECTIVE

THE AGENDA AND THE OBJECTIVES FOR THE DAY

WORKSHOP AGENDA

10:30	Welcome, Introductions & Network Equilibrium – Project Overview
10:40	Introduction to Voltage Limits Assessment (VLA) Task
10:50	VLA – Literature Review Findings

- Statutory framework standards- ESQCR, Distribution code, ER P28 and EN 50160
- Rationale behind existing standards
- Review and Change Processes

11:20 Open discussions- Existing Voltage Limits

- How are voltage limits applied in system planning, operations, customer service complaints etc?
  - System planning approaches and assumptions
  - Applications to demand and generation connections
  - Application under both system normal and abnormal
  - Systems with no 11kV or 33kV customer connections
  - Evidence of system voltages through monitoring, e.g. part of other LCNF projects
- How and to what extents are voltage limits constraining connections?
  - Are most restrictions applying to new demand or general connections?
  - Examples of how existing voltage limits are affecting new connections
  - Which methods are being applied to maintain connections within existing limits?

12:15 **Lunch**

12:45 Open Discussions – Future Voltage Limits

- Benefits of wider statutory and step change limits
- Technical barriers against the implementation of wider statutory and step change limits?
- Commercial barriers against the implementation of wider statutory and step change limits?

13:50 Next Steps and Thanks

14:00 Finish

WORKSHOP OBJECTIVE (1)

→ It is NOT:

- To suggest that voltage limits should change

→ But, to:

- Discuss and gather views on the existing 11kV and 33kV limits
- Explore benefits of and barriers to potential changes
- Inform a potential recommendation

WORKSHOP OBJECTIVE (2)

→ **So please:**

- Interact
- Interrupt
- Comment
- Challenge
- Share thoughts

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PROJECT OVERVIEW

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WPD INNOVATION STRATEGY

WESTERN POWER DISTRIBUTION NETWORK EQUILIBRIUM

Innovation Strategy

Networks

Demonstrating alternative investment strategies to facilitate the UK's Low Carbon Transition

Customers

Testing innovative solutions to make it simple for customers to connect Low Carbon Technologies

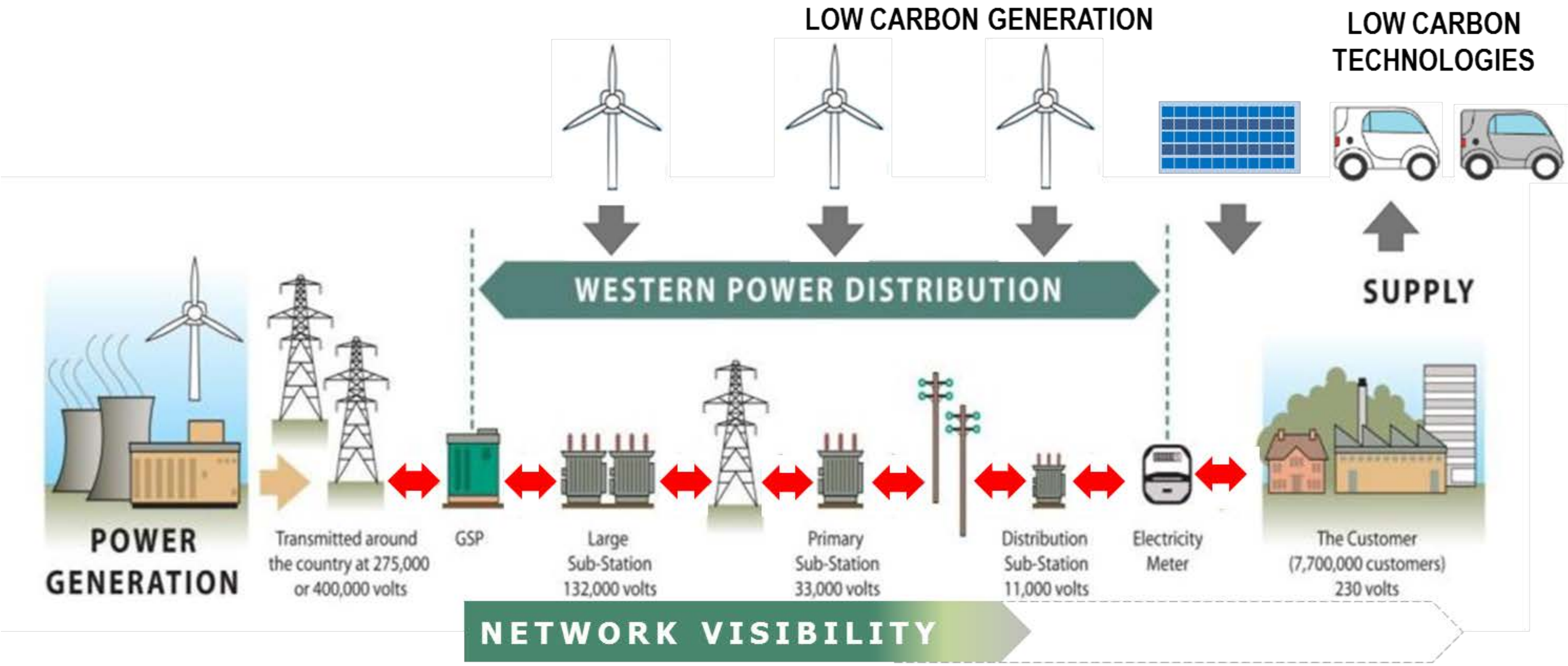
Performance

Developing new solutions to improve network and business performance

Stakeholder Engagement and Knowledge Management

- WESTERN POWER DISTRIBUTION NETWORK TEMPLATES
- WESTERN POWER DISTRIBUTION LOW CARBON HUB
- WESTERN POWER DISTRIBUTION SOLA BRISTOL
- WESTERN POWER DISTRIBUTION FALCON
- WESTERN POWER DISTRIBUTION FLEXDGRID
- WESTERN POWER DISTRIBUTION NETWORK EQUILIBRIUM
- WESTERN POWER DISTRIBUTION CLEAN ENERGY BALANCING
- WESTERN POWER DISTRIBUTION TELECOMS TEMPLATES
- WESTERN POWER DISTRIBUTION energy technologies institute POWER & HEAT
- WESTERN POWER DISTRIBUTION energy technologies institute ISENTROPIC
- WESTERN POWER DISTRIBUTION Innovate UK LV PLUS
- WESTERN POWER DISTRIBUTION Innovate UK WIRELESS HIGHWAYS
- WESTERN POWER DISTRIBUTION ECHO
- WESTERN POWER DISTRIBUTION COMMUNITY ENERGY ACTION
- WESTERN POWER DISTRIBUTION LOSS MITIGATION
- WESTERN POWER DISTRIBUTION SOLAR STORAGE
- WESTERN POWER DISTRIBUTION STATISTICAL RATINGS
- WESTERN POWER DISTRIBUTION D-SVC INTEGRATION
- WESTERN POWER DISTRIBUTION ELECTRIC BOULEVARDS
- WESTERN POWER DISTRIBUTION CARBON TRACING
- WESTERN POWER DISTRIBUTION SUNSHINE TARIFF
- WESTERN POWER DISTRIBUTION AERIAL INSPECTION

THE EVOLVING ELECTRICITY NETWORK



- Limited capacity
- Passive design / operation
- Centralised Generation
- Limited Visibility
- One-way power flow
- Load centric design

→

- Reduced headroom
- Increased Intelligence / Active Management
- Distributed Generation
- Need for increased visibility
- Two-way power flows
- Utilisation centric design

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SCALING UP PREVIOUS PROJECTS TO CATER FOR REAL WORLD COMPLEXITY

EVA

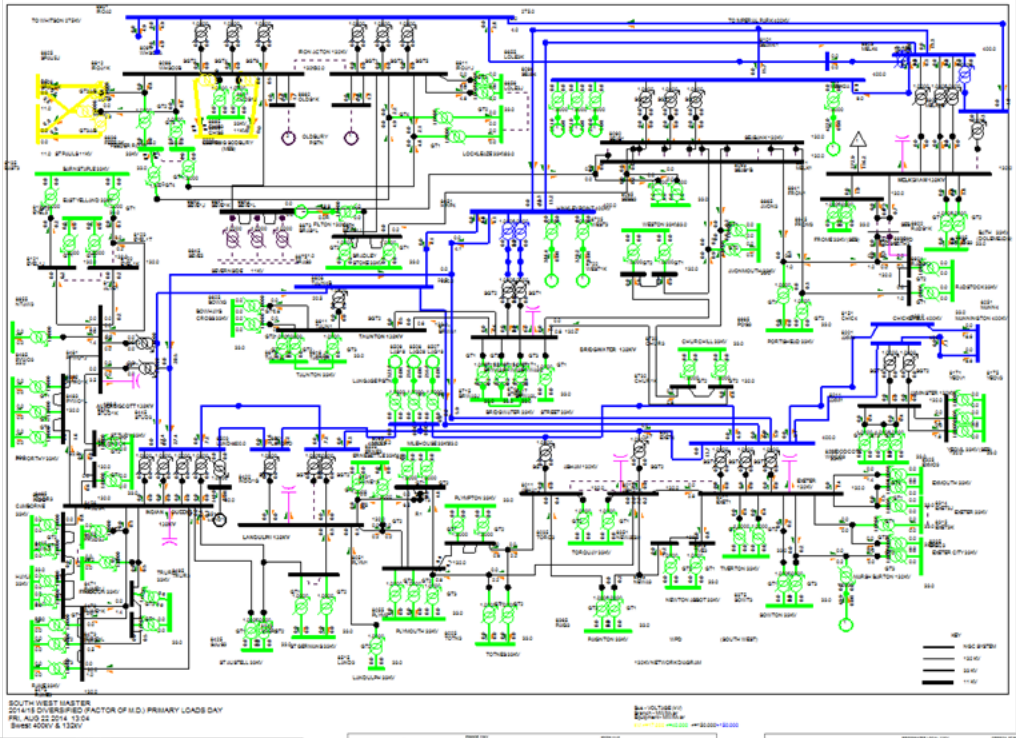
Enhanced Voltage Assessment

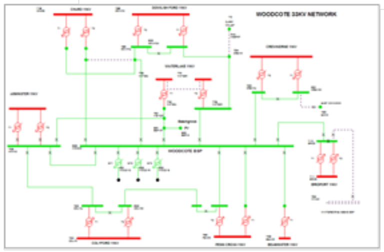
SVO

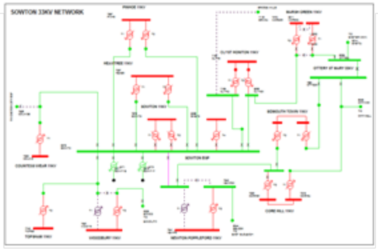
System Voltage Optimisation

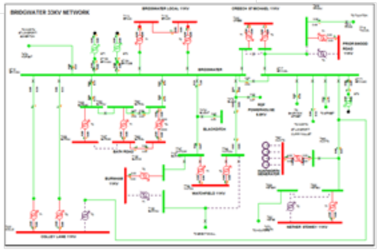
FPL

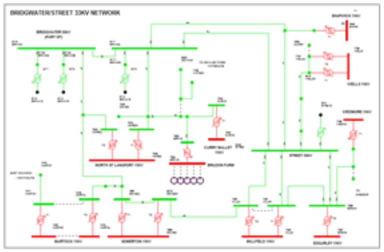
Flexible Power Links

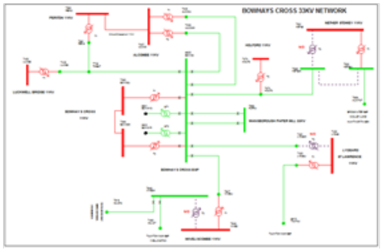


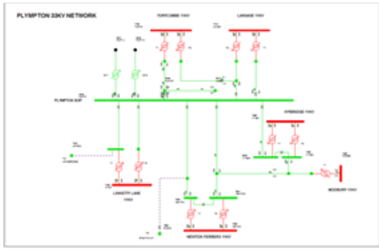












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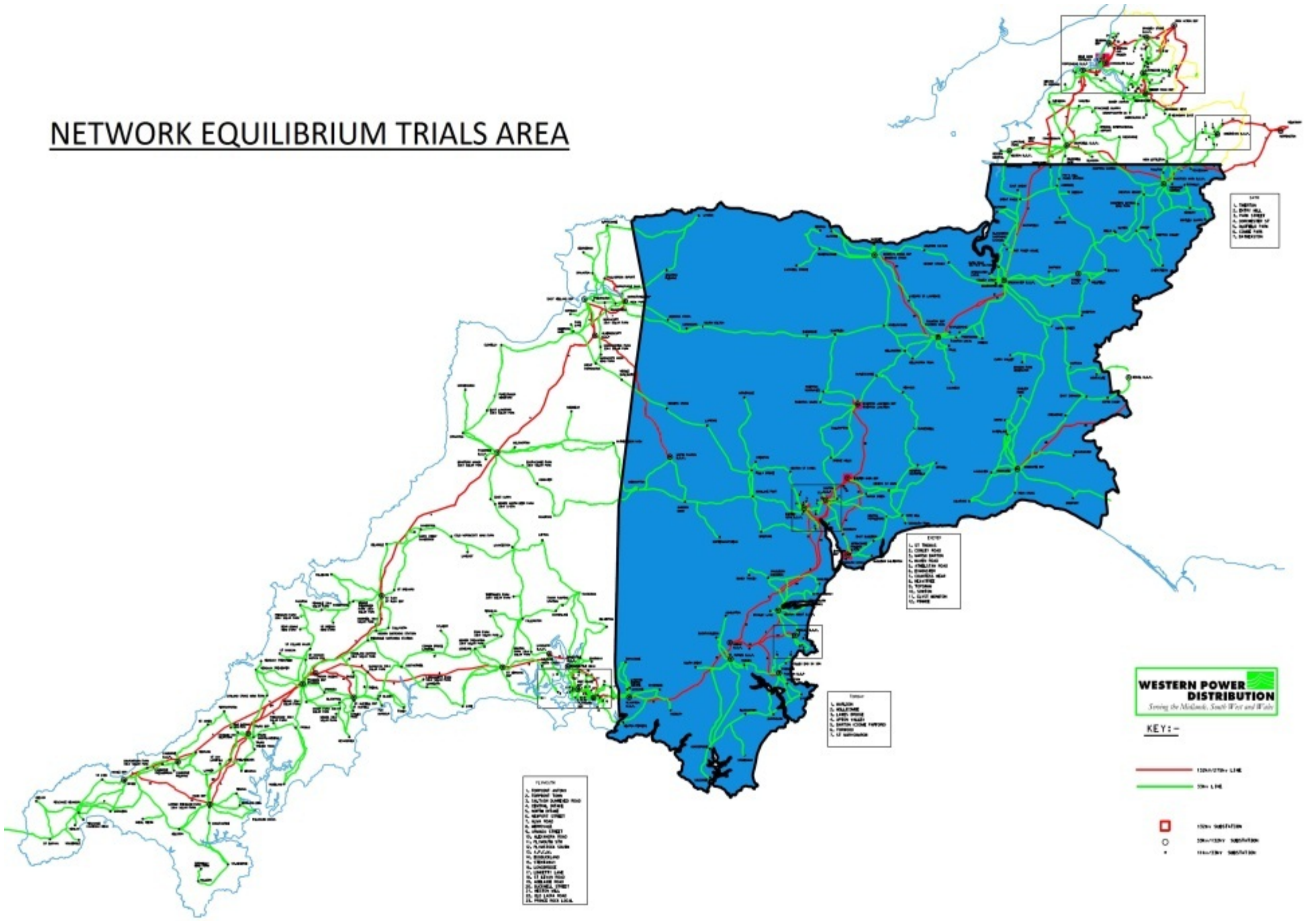
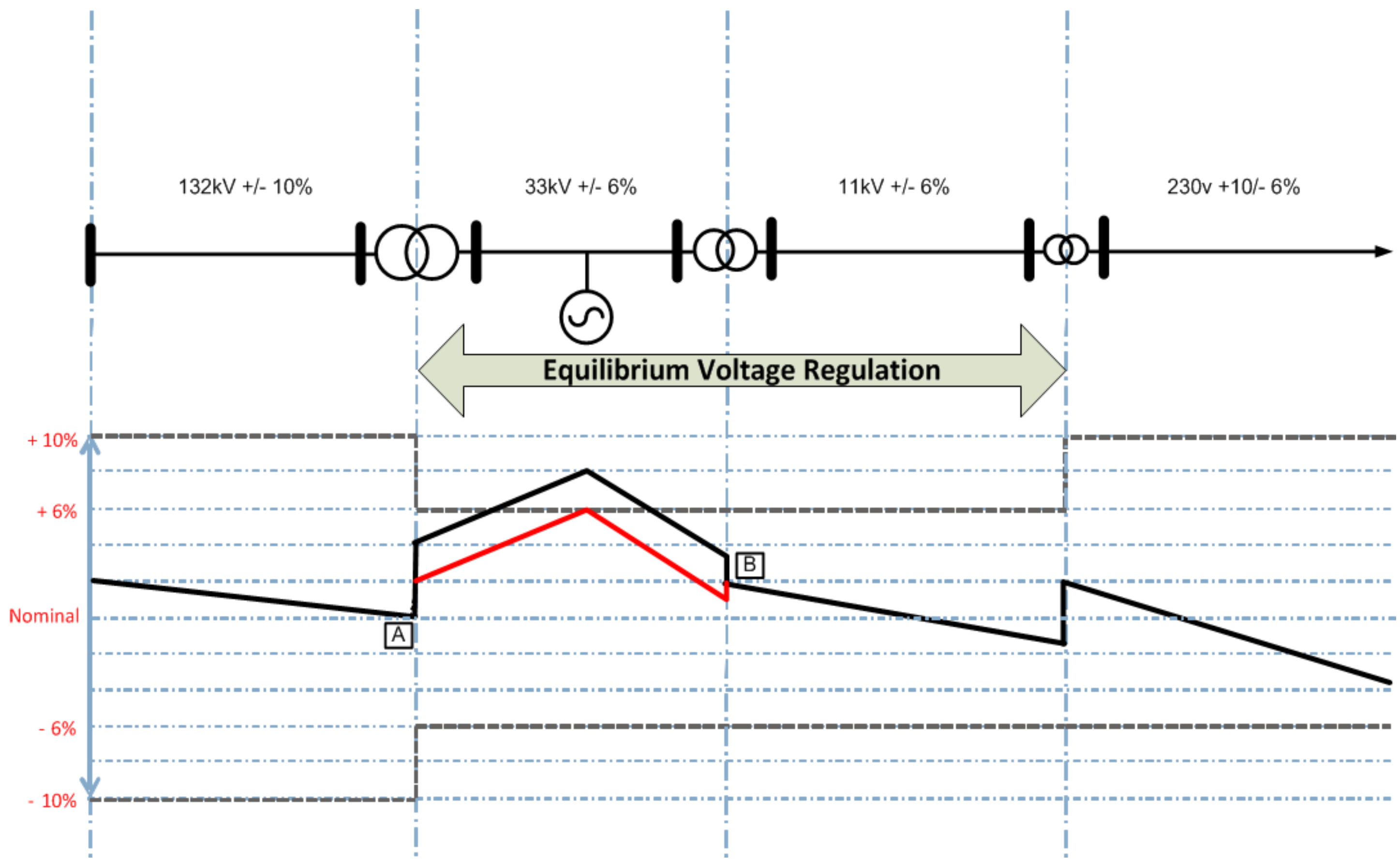
Method 1) Advanced Planning Tool (APT)

Current planning tools have been designed for passive network operation. Using these tools, it is very challenging to model complex network conditions accurately and replicate the effects of the new innovative technologies being installed on the network.



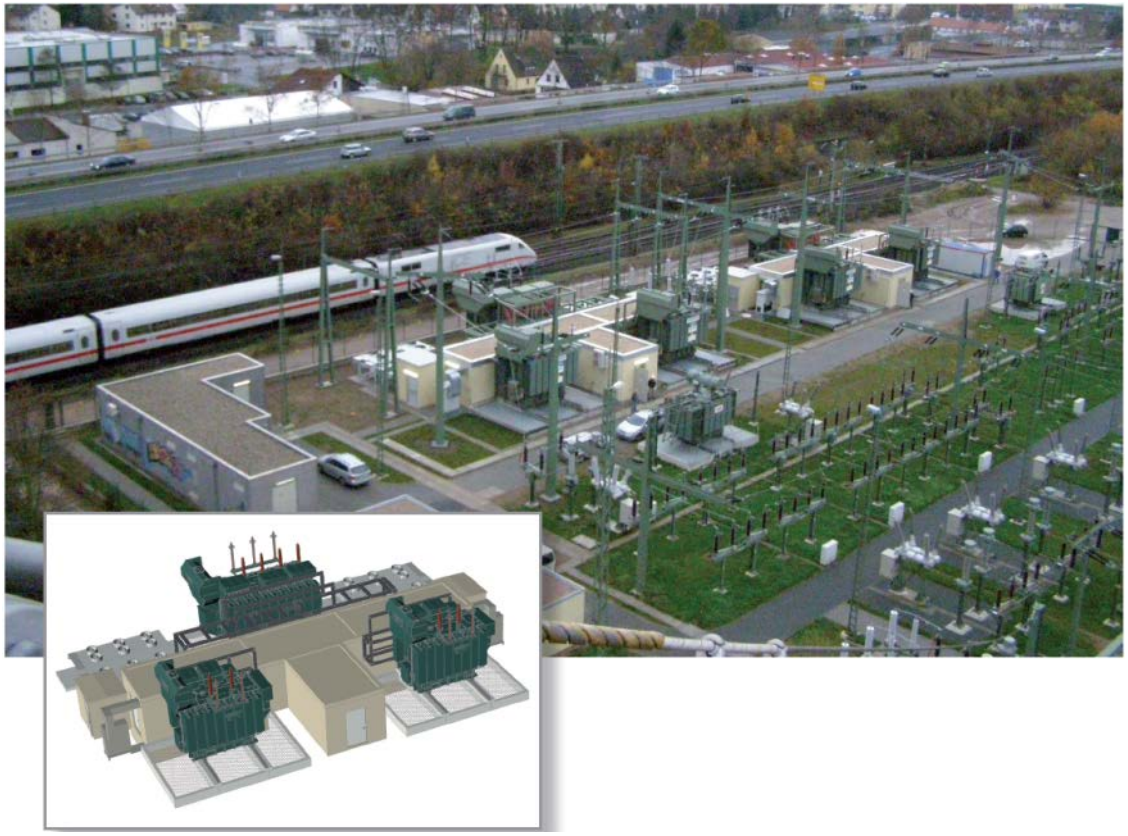
Method 2) System Voltage Optimisation (SVO)

The SVO Method will demonstrate how novel algorithms and Power System Analysis can be used to optimise distribution system voltage profiles over a wide area to unlock generation capacity, encompassing a significant part of WPD's South West licence area.



Method 3) Flexible Power Link (FPL)

The FPL Method will install innovative power electronic devices (back to back) to control real and reactive power flows between previously unconnected networks. These devices provide simultaneous power flow and voltage management capability and allow the power from one distribution system to be efficiently transferred to another.



PROJECT AIMS

→ Increase granularity of Voltage and Power flow assessments

- Explore potential amendments to ENA Engineering Recommendations and statutory voltage limits in 11kV & 33kV to unlock capacity for increased levels of low carbon technologies

→ Demonstrate how better outage planning can keep more customers connected to the network, (especially post faults)

→ Develop policies, guidelines and tools which will be ready for adoption by other GB DNOs

→ Improve the resilience of electricity networks through Flexible Power Link (FPL) technologies which can control voltage at 33kV and allow power to be transferred between two previously distinct distribution systems

→ Increase the firm capacity of substations which means that security of supply to distribution customers can be improved during outage conditions

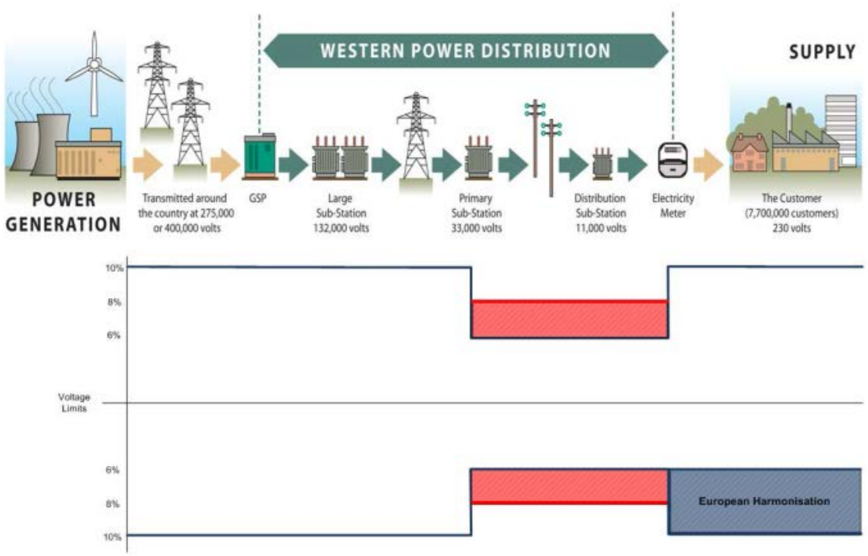
VOLTAGE LIMITS ASSESSMENT

INTRODUCTION TO THE VLA TASK

VOLTAGE LIMITS ASSESSMENT (1)

WPD, like all UK DNOs, operate 11kV and 33kV networks within the ±6% statutory limits and the voltage step change limitations. Statutory limits have been unchanged since 1937. This underpins the existing voltage standards.

Widening the limits will allow more Distributed Generation to connect



New Learning

- Evidencing the limiting factors and safety margins for DNO and customer equipment
- Sharing findings with DNOs and appropriate standards bodies

Benefits

- Championing a change in operational voltage limits
- Amending voltage limits for 33kV and 11kV networks would quickly and effectively unlock additional capacity for generation and demand customers

VOLTAGE LIMITS ASSESSMENT (2)

→ Introduction to the VLA task

- Theoretical investigation into whether steady-state statutory voltage limits and voltage step change limits for the 11kV and 33kV networks could be amended

- The second aspect of the Enhanced Voltage Assessment (EVA) method of Network Equilibrium

- Statutory LV voltage tolerances are ***not*** in the scope

VOLTAGE LIMITS ASSESSMENT (3)

→ Introduction to the VLA task

- Review of the steady-state voltage limits in the UK, the EU and private networks
- Review of the voltage step change limits in the UK, the EU and private networks
- Technical and commercial barriers to a potential change in voltage limits
- Literature review of Conservation Voltage Reduction (CVR)
- Voltage assessment questionnaire

VOLTAGE LIMITS ASSESSMENT (4)

→ Why the need for a VLA?

- Voltages can be a limitation to connecting additional generation and/or demand
- Limitation to the connection of renewable energy systems
- Limitation to the electrification of transport and heat

VLA FINDINGS

LITERATURE REVIEW FINDINGS

VLA LITERATURE REVIEW FINDINGS (1)

→ Overview

- Issue of a Voltage Limits Assessment Questionnaire to industry stakeholders
- Review of present and historical steady-state voltage limits in the UK and the EU
- Review of present and historical step change voltage limits in the UK and the EU
- Investigation of rationale and governance
- Review of Conservation Voltage Reduction (CVR) applications worldwide

VLA LITERATURE REVIEW FINDINGS (2)

→ VLA Questionnaire

- Aimed at Network Operators, Equipment Manufacturers, Technical Experts and Academia
- Seek information regarding how voltage limits are currently implemented in distribution networks of the UK and EU
- Identify constraints they impose to the relevant stakeholders operating or connecting to the networks
- Explore amendments to existing steady-state voltage limits and step change limits where applicable, highlighting both limitations and opportunities for change

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VLA LITERATURE REVIEW FINDINGS (3)

→ Present UK statutory steady-state supply voltage limits

ESQCR 2002		
LV	**>LV & <132kV**	**≥132kV**
230V +10% / -6%	±6%	±10%

- Exemptions might be applicable with the written consent of the DNO, the supplier and the customer

- No details as to how compliance with the requirements should be assessed

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VLA LITERATURE REVIEW FINDINGS (4)

→ **Present EU steady-state supply voltage limits**

EN 50160:2010		
U_n ≤1kV	**1< U_n ≤36kV**	**36kV< U_n ≤150kV**
230V ±10% for 95% of a week & 230V +10% / -15% for 100% of a week	U_c ±10% for 99% of a week & U_c ±15% for 100% of a week	-

- U_c is the agreed voltage at the customer's terminals
- Exemptions apply for "special remote" customers and those not connected onto an interconnected system

VLA LITERATURE REVIEW FINDINGS (5)

→ Present UK voltage step change limits

Distribution Code (Issue 26 – Sep 2015)		
Infrequent, planned events	**Unplanned events (e.g. faults)**	**Multi-Tx site energisation (< than once a year)**
±3%	±10%	±10%

- "…*after all the generation set AVR and static VAR compensator actions, and transient decay*…"
- "…*before any other automatic or manual tap-changing and switching actions*…"
- Not explicitly mentioned where exactly on the system voltage step change is considered or which voltage is taken as the reference to calculate the % change

VLA LITERATURE REVIEW FINDINGS (6)

→ Present UK voltage step change limits

ENA ER P28 (1989)		
> once per 10min	**< once per 10min & > once per several months**	**< once per several months**
<3%	±3%	at DNO discretion

- 3-stage assessment, increased complexity with each stage
- Voltages considered at the PCC
- Not explicitly mentioned which voltage is taken as the reference (i.e. the nominal, the declared or the one at the instant of the event)

VLA LITERATURE REVIEW FINDINGS (7)

→ Present EU voltage step change limits

EN 50160:2010 (Indicative Values)			
	U_n ≤1kV	1< U_n ≤36kV	36kV< U_n ≤150kV
Generally	5% U_n	4% U_c	-
Some times per day, short duration	10% U_n	6% U_c	-

- The definition of a Rapid Voltage Change (RVC) is adopted
- If the voltage during a change crosses the voltage dip/swell threshold (i.e. 90%/110% of U_n for LV and U_c for MV/HV) then the event is classified as a voltage dip/swell instead of an RVC

VLA LITERATURE REVIEW FINDINGS (8)

→ Rationale behind steady-state limits (present and historical)?

- Limits have not changed since the Electricity Supply Regulations of 1937
- Rationale difficult to grasp, not mentioned clearly in the regulations or the standards
- BS17 “Electrical Machinery” (1904): a ±10% variation is permitted in order for the machines to be able to support the voltages
- A voltage drop of 10% is also regarded to be Ferranti’s common practice of system design in the 19^{th} century (anecdotal)

VLA LITERATURE REVIEW FINDINGS (9)

→ International Approach

- IEC 60038: "*the voltage ranges… to be the most appropriate ones as a basis for design and testing of electrical equipment and systems*"
- ITIC curve (2000) of IT equipment shows a 10% tolerance
- EN 50160 is based on compatibility levels and probabilistic analysis

VLA LITERATURE REVIEW FINDINGS (10)

→ Rationale behind step change limits?

- **ER P28**: based on flicker severity and customer visual annoyance due to voltage step changes; equipment immunity consideration
- **Distribution Code**: the 3% limit is in accordance with ER P28; no clear reasoning behind the 10% limit
- **EN 50160** only gives indicative values, whose calculation is not detailed

VLA LITERATURE REVIEW FINDINGS (11)

→ Governance

- **ESQCR**: issued by the pertinent ministry (e.g. DECC)
- **EN 50160**: CENELEC issues EN documents (as well as HD) that member countries adapt to and issue as national standards (e.g. via BSI in the UK)
- **Distribution Code**: maintained by its Review Panel (DCRP), which involves the DNOs, Ofgem and system users
- **ER P28**: Published by the ENA; a Working Group, sanctioned by the DCRP and the Grid Code Review Panel (GCRP), is currently reviewing it

EXISTING VOLTAGE LIMITS

OPEN DISCUSSION

EXISTING VOLTAGE LIMITS (1)

→ **How are voltage limits applied in system planning, operations, customer service complaints etc.?**

- System planning approaches and assumptions?
- Demand and generation connections?
- System normal and abnormal?
- Systems with no 11kV or 33kV customers?
- Evidence through monitoring (e.g. other LCNF projects)?

EXISTING VOLTAGE LIMITS (2)

→ **How and to what extent are voltage limits constraining connections?**

- Most restrictions applying to new demand or new generation connections?
- Any examples?
- How are connections maintained within limits?

ANY QUESTIONS?

JUST BEFORE LUNCH BREAK…

LUNCH BREAK

PLEASE, RECONVENE IN 30 MINUTES

FUTURE VOLTAGE LIMITS?

OPEN DISCUSSION

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POTENTIAL BENEFITS

→ **What are the potential benefits of wider statutory and step change limits?**

- Reinforcement deferment and/or avoidance?
- Increased speed of connections?
- Increased uptake of renewable generation?
- Carbon reductions due to increased uptake of renewables?
- Allow for greater demand reduction through CVR?

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POSSIBLE FUTURE LIMITS

→ Where could future statutory and step change limits lie?

- Additional headroom, legroom or both?
- Indicative values?
- What could determine new tolerance bands in each case?

TECHNICAL BARRIERS – PLANNING

→ What are the technical barriers against the implementation of wider statutory and step change limits?

- Thermal limits and fault levels?
- Existing tap-changer ranges?
- Implications at LV?
- Transmission system impact?

TECHNICAL BARRIERS – OPERATION

→ **What are the technical barriers against the implementation of wider statutory and step change limits?**

- Existing voltage control schemes?
- Future voltage control schemes? Voltage regulators, OLTC on distribution transformers etc.
- G59 settings? Undesired generator tripping?
- Voltage unbalance detection?
- Grid Code OC6 clash?

TECHNICAL BARRIERS – OTHER

→ **What are the technical barriers against the implementation of wider statutory and step change limits?**

- Manufacturing standards?
- Other standards?
- Customer discernible effects? Complaints?

COMMERCIAL BARRIERS

→ **What are the commercial barriers against the implementation of wider statutory and step change limits?**

- Customer contracts and agreements?

- Modification costs?
- Any other issues?

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FUTURE VOLTAGE LIMITS?

Questionnaire Responses

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VLA QUESTIONNAIRE (1)

→ Responses

- Positive perception, benefits relating to reduced network reinforcements and quicker network connections highlighted

- Need for wider system coordination of voltage control

- Increased upper steady-state limit
  - Voltage withstand capabilities of distribution equipment
  - Higher fault levels, lower power quality?

- Decreased lower steady-state limit
  - Reduced network losses, improvement of asset life
  - Operation of sensitive loads, e.g. motors
  - OC6 implications

VLA QUESTIONNAIRE (2)

→ **Responses**

- Step change limits
  - (Mal)operation of sensitive and protective equipment
  - ER P28 Working Group proposals and GC076 modification proposal – alignment and impact

- Impact on higher voltages
  - Different paradigm of tap-change voltage control on HV networks
  - Bottom-up approach on voltage control required (reverse power flows)
  - Reactive power reserves at distribution level need to support transmission system demand

- Impact on lower voltages
  - LV reinforcements
  - Sensitive equipment (e.g. lighting)
  - Flexibility of the HV customers' transformation equipment

NEXT STEPS

In The Near Future…

NEXT STEPS

→ In the near future, WPD shall:

- Publish the Voltage Limits Assessment reports as part of Network Equilibrium (January 2016)
- Organise & disseminate knowledge at future events
- Share learning and progress on Network Equilibrium as a whole
- If appropriate, pass all findings on to ENA for them to form a future Working Group to investigate in greater detail

ANY QUESTIONS?

AOB OR ANY REMARKS?

THANK YOU!

FOR YOUR CONTRIBUTIONS AND VALUABLE INSIGHT