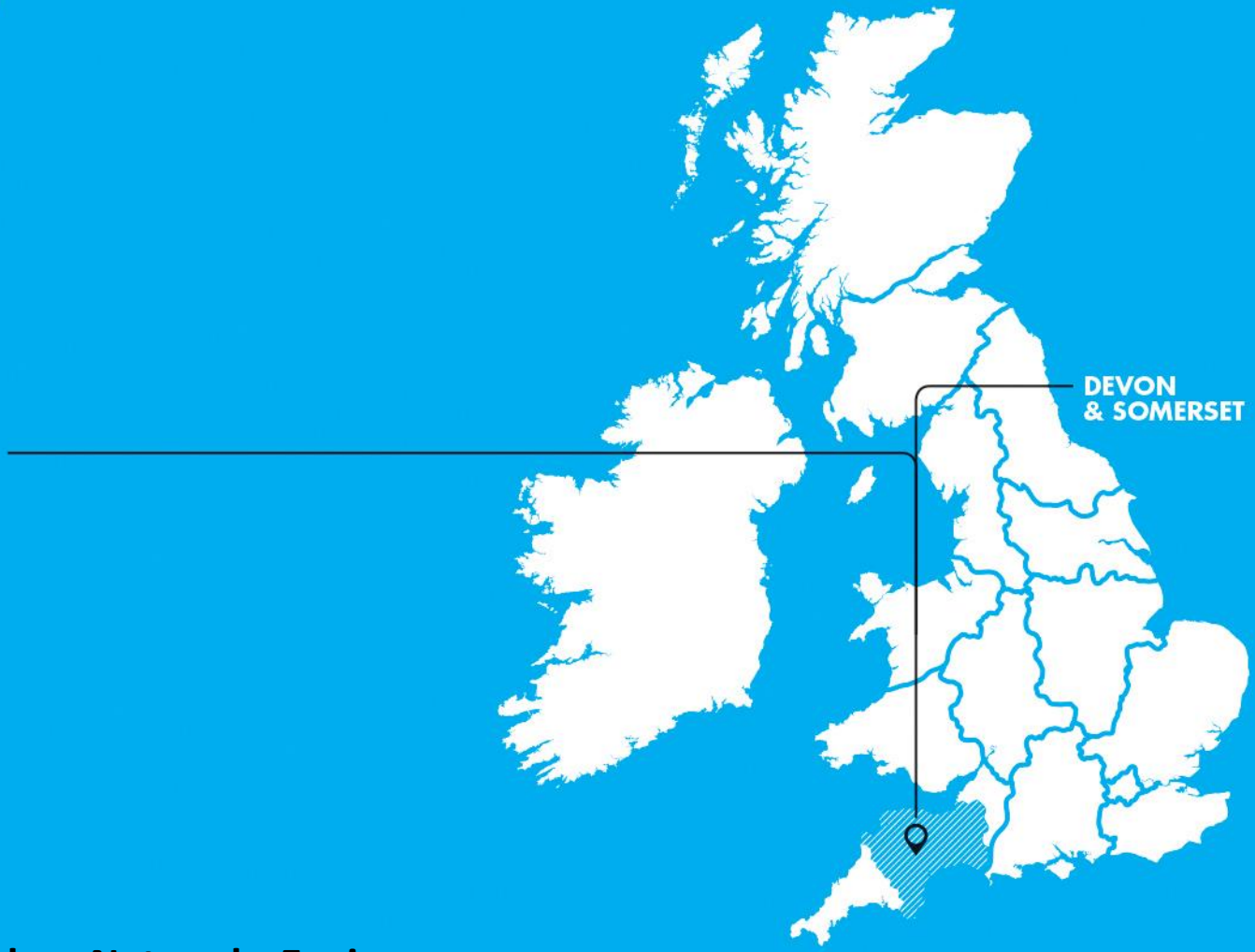
WESTERN POWER DISTRIBUTION

NETWORK EQUILIBRIUM

BALANCING GENERATION AND DEMAND



Network Equilibrium

Balancing Act Conference

Thursday 8th September 2016

Yiango Mavrocostanti

Innovation and Low Carbon Networks Engineer

Western Power Distribution

LCN Fund
Low Carbon Networks

Outline

- WPD Innovation - Introduction
- Network Equilibrium overview
- What we have done
- What we will do next
- What we learned
- Summary

WESTERN POWER DISTRIBUTION NETWORK EQUILIBRIUM

WESTERN POWER DISTRIBUTION PROTEUS NEW

WESTERN POWER DISTRIBUTION FLEXDGRID

WESTERN POWER DISTRIBUTION PLUGS AND SOCKETS

WESTERN POWER DISTRIBUTION SOLA BRISTOL

WESTERN POWER DISTRIBUTION LOW CARBON HUB

WESTERN POWER DISTRIBUTION OPEN LV NEW

WESTERN POWER DISTRIBUTION NETWORK EQUILIBRIUM

WESTERN POWER DISTRIBUTION SMART ENERGY ISLES

WESTERN POWER DISTRIBUTION NETWORK TEMPLATES

WESTERN POWER DISTRIBUTION FALCON

Future Networks Programme

Assets

- Telemetry
- Decision support
- Improved assets
- New assets
- Flexibility
- Automation
- Incident response

Customers

- New connections
- Upgrades
- Information
- Self Serve
- Products/Service
- Tariffs
- Communities

Operations

- Reliability
- Forecasting
- DSO
- DSR
- GBSO Interface
- Efficiency
- SHE and Security

Network and Customer Data

- **Airborne Inspections**
- **AIRSTART[1]**
- **Telecoms Templates**
- **Superconducting Cable**
- **SF6 Alternatives**
- **MVDC Test Lab**
- **Smart Energy Laboratory**
- **Statistical Ratings**
- **Primary Network Power Quality Analysis**
- **Hybrid Heat Pump Demonstration**
- **Hydrogen Heat & Fleet**
- **Carbon Tracing**
- **HV Voltage Control**
- **Solar Storage**
- **LV Connect and Manage**
- **Sunshine Tariff**
- **CarConnect**
- **Industrial & Commercial Storage**
- **DSO/SO Shared Services**
- **Project Sync**
- **Project Entire: Flexible Power**
- **Integrated Network Model**
- **Smart Meter Exploitation**
- **Distribution Operability Framework**
- **Data Analytics**
- **Voltage Level Assessment**
- **LV Connectivity**
- **Smart Systems and Heat[2]**

Note: 1 – Funded by Aerospace Technology Institution; Note 2 – Funded by the Energy Systems Catapult

Network Equilibrium – An Overview

- £13 million Tier 2 project
- Project area: Part of WPD's South West Network.
- Started in March 2015, finishes June 2019.

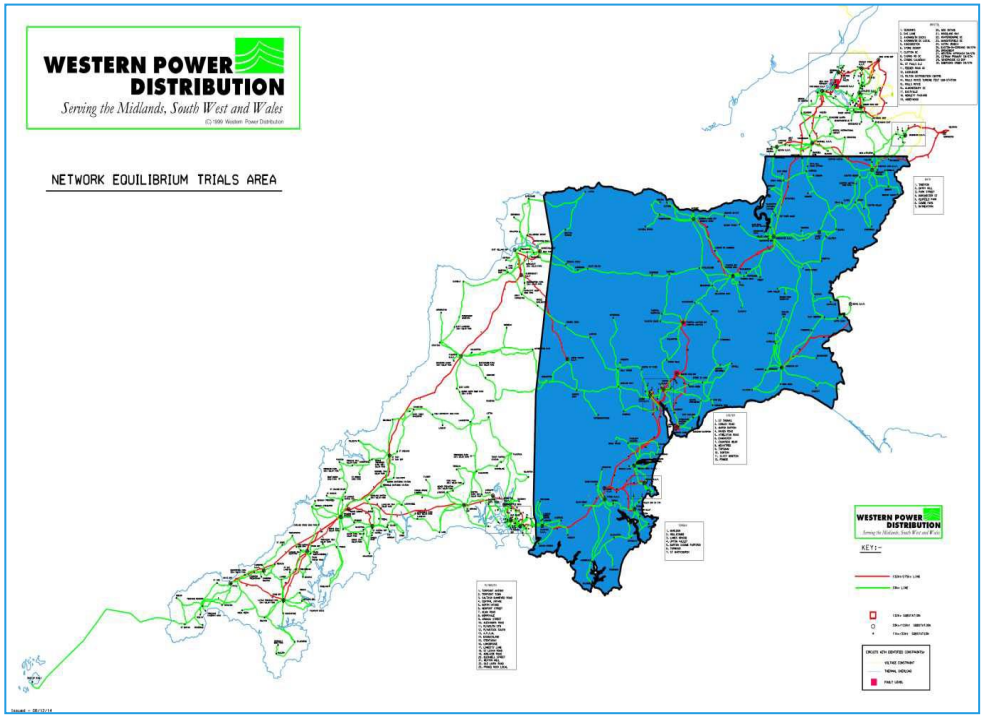
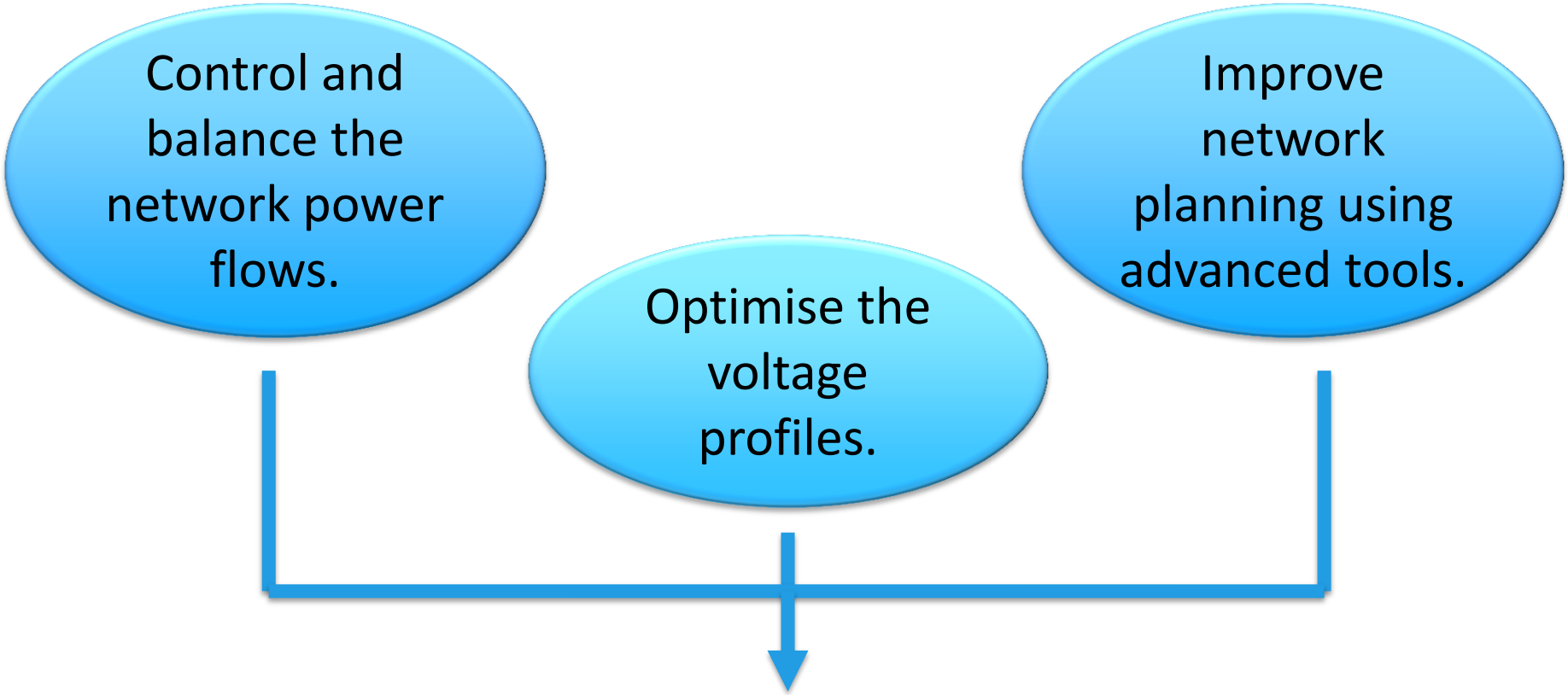


Figure 1: Network Equilibrium Project area

Network Equilibrium – Project Objectives



To release network capacity and allow more Low Carbon Technologies to connect

Network Equilibrium – The Techniques

1. EVA

Enhanced Voltage Assessment

- **Part 1:** Advanced Planning Tool – better network planning.
- **Part 2:** Investigation into potential amendment of statutory voltage limits.

2. SVO

System Voltage Optimisation

- Centralised, real-time Voltage Control system in 33kV and 11kV networks.

3. FPL

Flexible Power Link

- Back-to-back voltage source converter installed between two previously unconnected Bulk Supply Points.

Network Equilibrium – Enhanced Voltage Assessment

PART 1: Advanced Planning Tool (APT)

What is the problem we want to solve?

- Current planning procedures based on worst case scenarios.

  → These might never occur – Underestimated network capacity!

- Different tools used for the 11kV network and different tools for the upper voltage levels.

  → Unable to see operation of entire network.

Network Equilibrium – Enhanced Voltage Assessment

PART 1: Advanced Planning Tool (APT)

- Better visibility of all voltage levels.
- Analysis using:
  1. Historic time-series SCADA data.
  2. Typical profiles.
  3. 48-hour forecast profiles.
- Users: Design Engineers, Control Engineers, Outage planners.

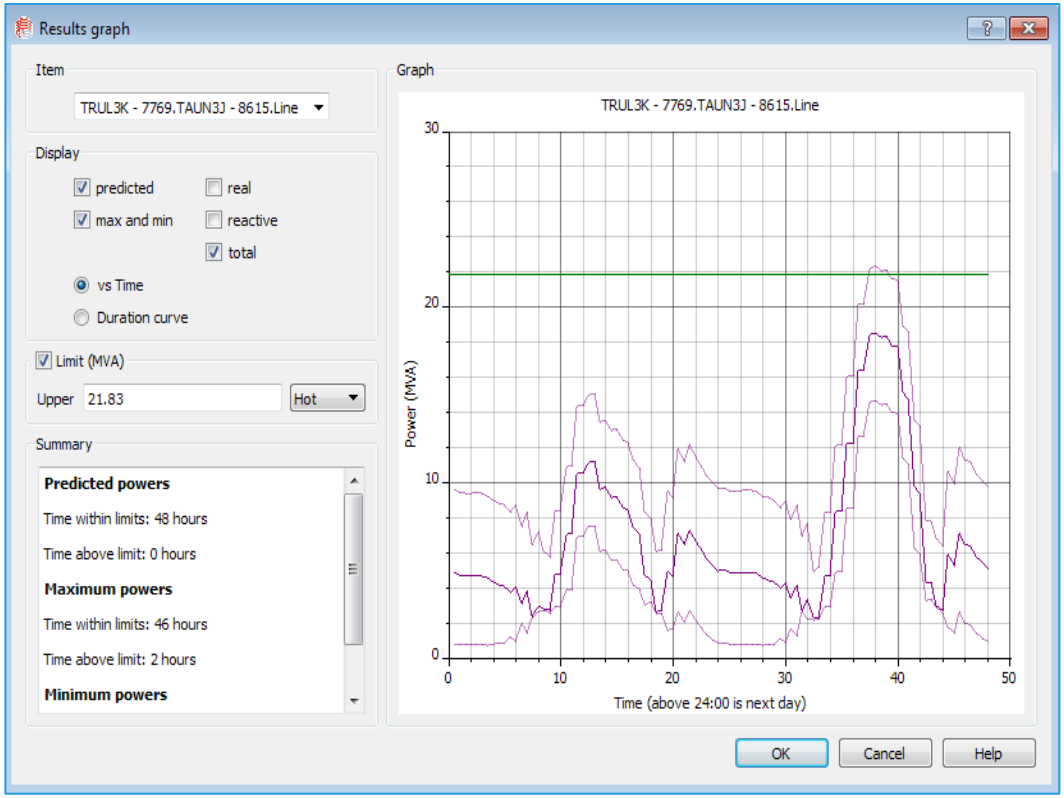


Figure 2: APT Screenshot

Network Equilibrium – Enhanced Voltage Assessment

PART 1: Advanced Planning Tool (APT)

- Evaluation of network capacity.
- Easy identification of constrained parts of the network and historic patterns.
- Graphical view of results.
- Modelling of SVO and FPL.

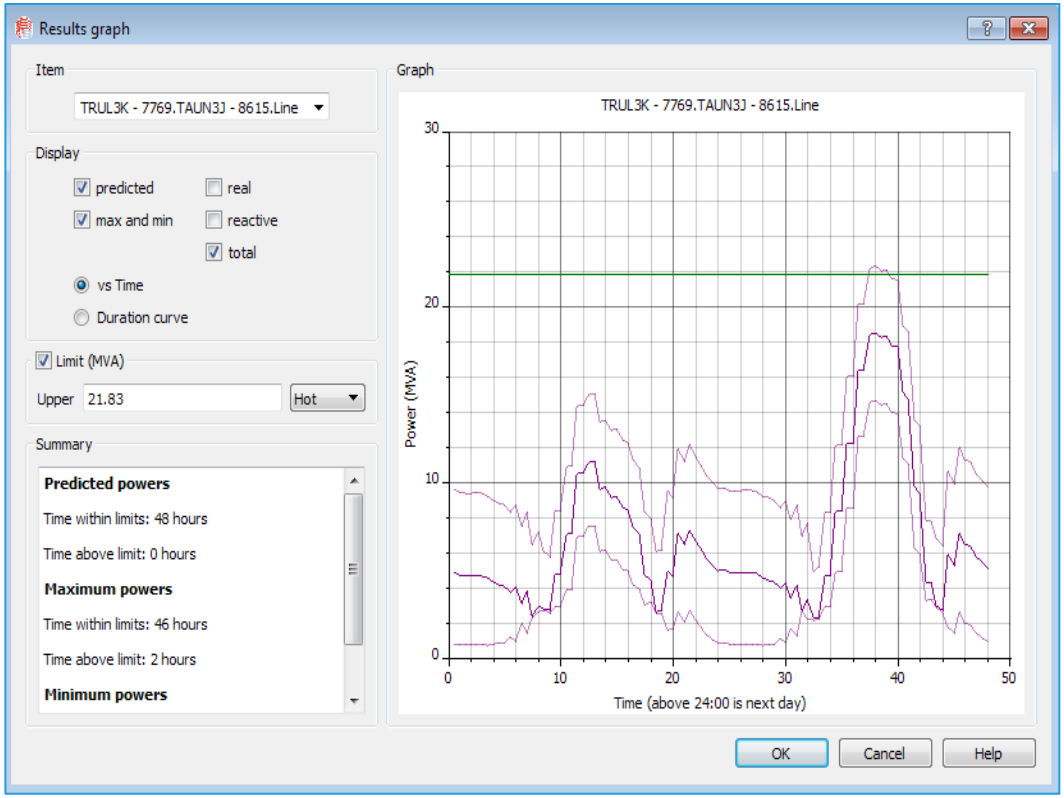


Figure 2: APT Screenshot

Network Equilibrium – Enhanced Voltage Assessment

PART 1: Advanced Planning Tool (APT)

What we have done so far

- Currently being developed (TNEI).
- Models for demand and generation typical and forecast profiles completed.
- Network model created using information from WPD's Geographical Information System.
- SVO and FPL plugins have been created and are being tested.
- FTP link established with Met-Office and forecast profiles have been generated since January 2016.

Network Equilibrium – Enhanced Voltage Assessment

PART 1: Advanced Planning Tool (APT)

Next Steps

- Finish tool development: Q1 2017.
- Testing of tool: Q1 2017.
- Training and trial: Q3 2017.

Network Equilibrium – Enhanced Voltage Assessment

PART 2- Voltage Limits Assessment

What is the problem we want to solve?

- Statutory voltage limits set at +/- 6% in 11kV and 33kV networks.

→ Capacity for new connections depends on headroom available before upper voltage limit is reached.

→ Rationale behind existing limits unknown.

WESTERN POWER DISTRIBUTION
NETWORK EQUILIBRIUM

Network Equilibrium – Enhanced Voltage Assessment

PART 2- Voltage Limits Assessment (VLA)

Theoretical investigation

Could the 11kV and 33kV statutory voltage limits be widened to release network capacity?

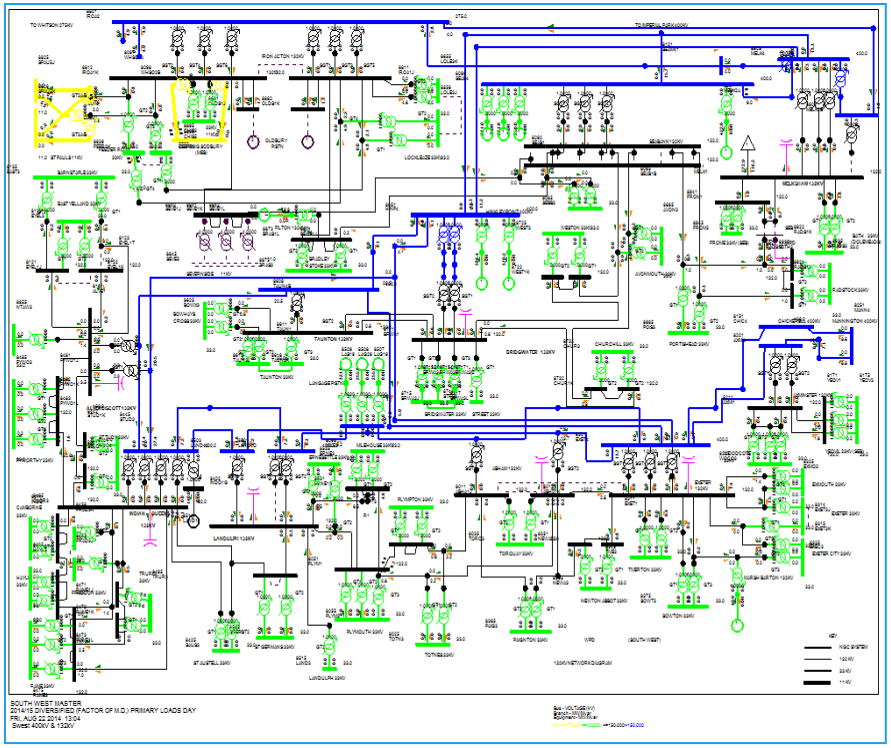


Figure 3: South West Network Single Line Diagram

Network Equilibrium – Enhanced Voltage Assessment

PART 2- Voltage Limits Assessment (VLA)

- Study completed by Parsons Brinckerhoff.

- Included literature reviews, stakeholder engagement, equipment specification investigations and system studies.

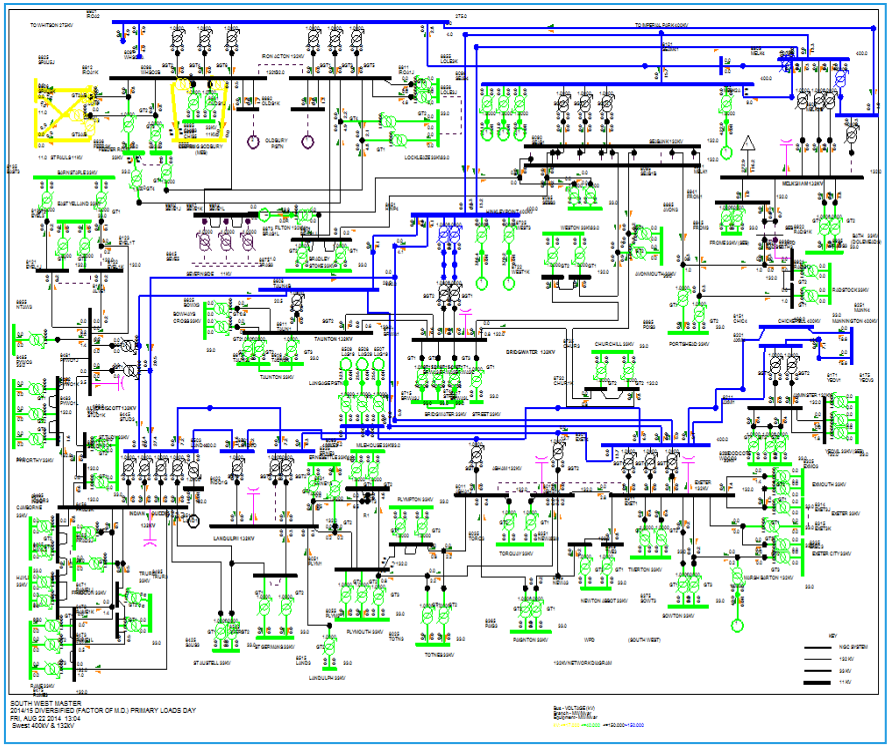


Figure 3: South West Network Single Line Diagram

Network Equilibrium – Enhanced Voltage Assessment

PART 2: Voltage Limits Assessment (VLA)

Study completed – Main Outputs

- Industry supportive of investigations.
- A new voltage range of +-10% was considered.
- Majority of 11kV and 33kV connected equipment would not need replacement.
- This range advisable for 33kV but tighter range for 11kV is suggested due to voltage regulation issues.

Network Equilibrium – Enhanced Voltage Assessment

PART 2: Voltage Limits Assessment (VLA)

Study completed – Main Outputs

- Step change limits to be maintained.
- Study and outputs forwarded to industry.
- Further consultation – voltage limit working groups.
- Consultation with customers, UK and EU regulators and studies on other parts of the UK network are suggested.

Network Equilibrium – System Voltage Optimisation

What is the problem we want to solve?

Traditional Voltage Control philosophy

- Relays at substations Control On Load Tap Changers.
- Keep voltage at substation close to pre-determined value.
- This target voltage value historically set high.
- Suitable for demand dominated networks.

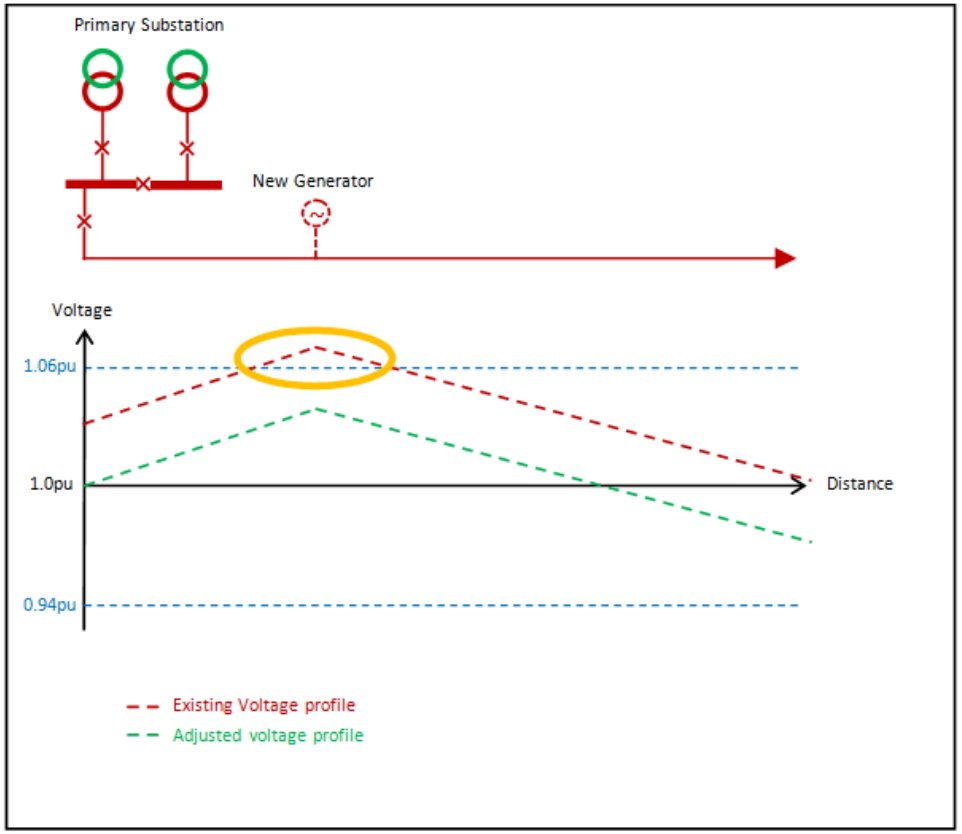


Figure 4: Traditional and amended voltage profiles

Network Equilibrium – System Voltage Optimisation

What is the problem we want to solve?

Traditional Voltage Control philosophy

- Restrictive in modern networks.

Limits available network capacity!

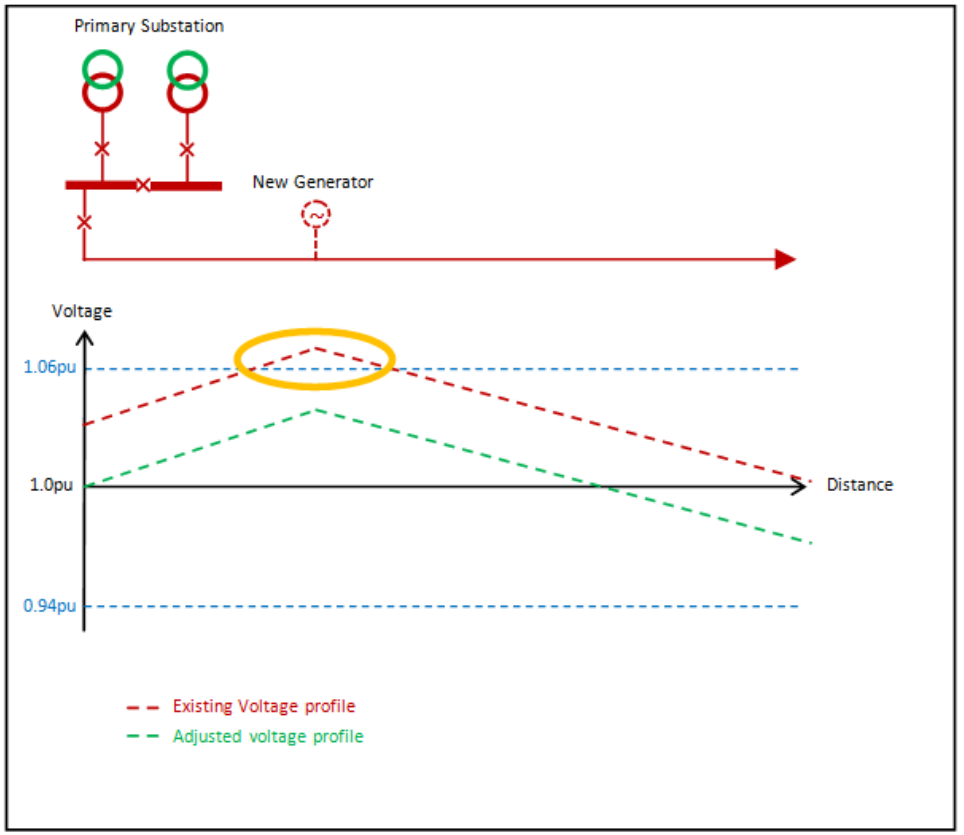


Figure 4: Traditional and amended voltage profiles

Network Equilibrium – System Voltage Optimisation

Dynamically adjust the previously static target voltage at the substation based on real-time operating conditions.

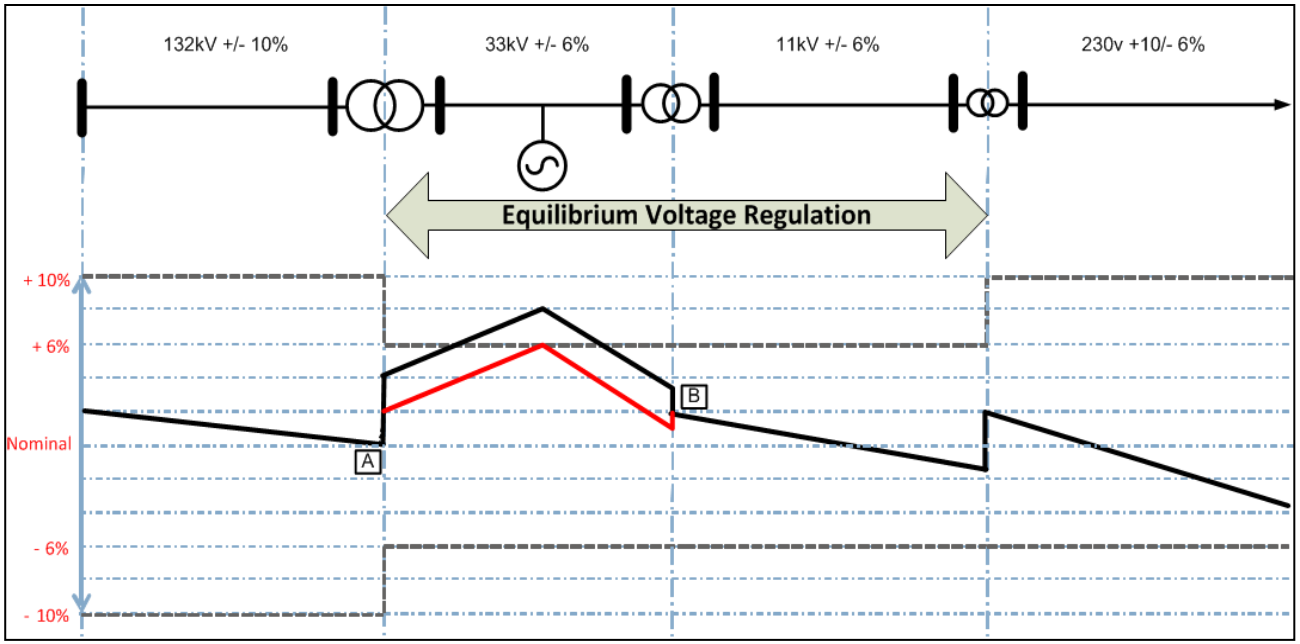


Figure 5: System Voltage Optimisation operation

Network Equilibrium – System Voltage Optimisation

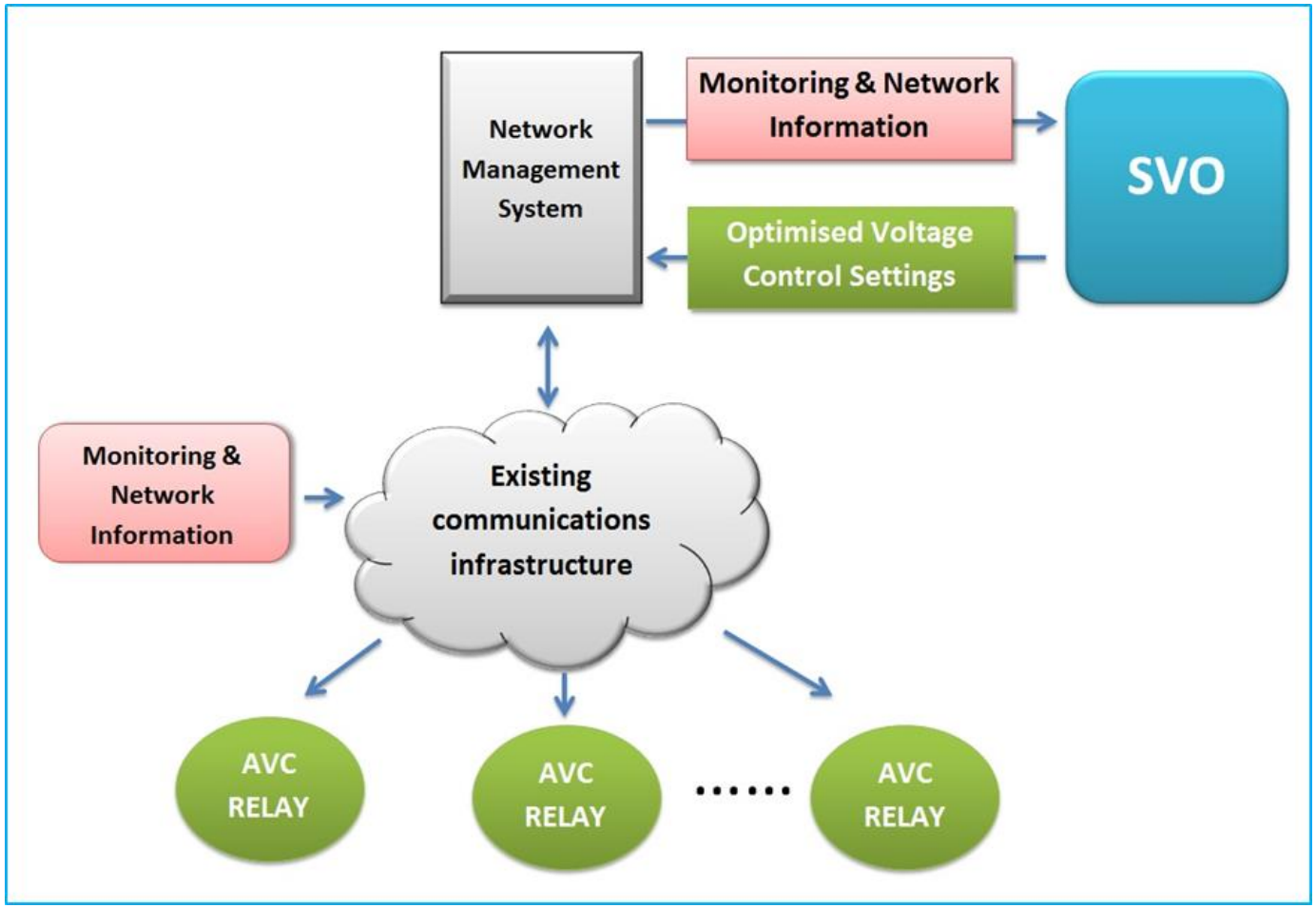


Figure 6: System Voltage Optimisation Architecture

Network Equilibrium – System Voltage Optimisation

What we have done so far

- Selected the 8 BSPs and 8 Primaries to be controlled by SVO.
- Identified the AVC relays that will need to be replaced and associated site works required.
- Working with Siemens on system design – SVO based on Siemens' Spectrum Power 5 technology.
- WPD'S IT, PowerOn and Engineering Design teams involved in design process.
- Produced the first designs for relay replacements.
- Currently creating the SVO network model.
- Produced extract of ICCP Bilateral Table linking SVO model to monitoring information to be received.

Network Equilibrium – System Voltage Optimisation

Next Steps

- System Design Complete by Q3 2016.
- Preparation for testing Q1 2017.
- Site works complete by Q3 2017.
- Testing and commissioning of system complete by Q3 2017.
- System live Q3/Q4 2017.
- Trials commence Q4 2017.

Network Equilibrium – Flexible Power Link

What is the problem we want to solve?

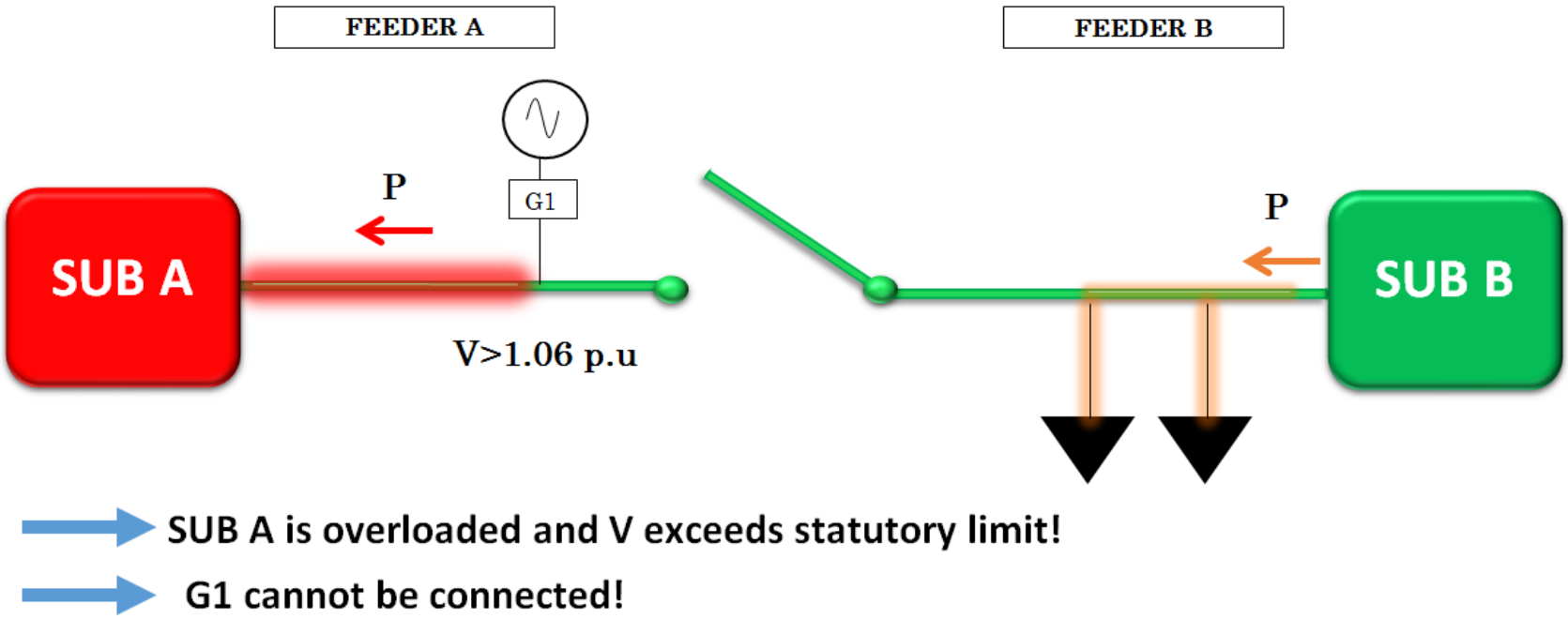
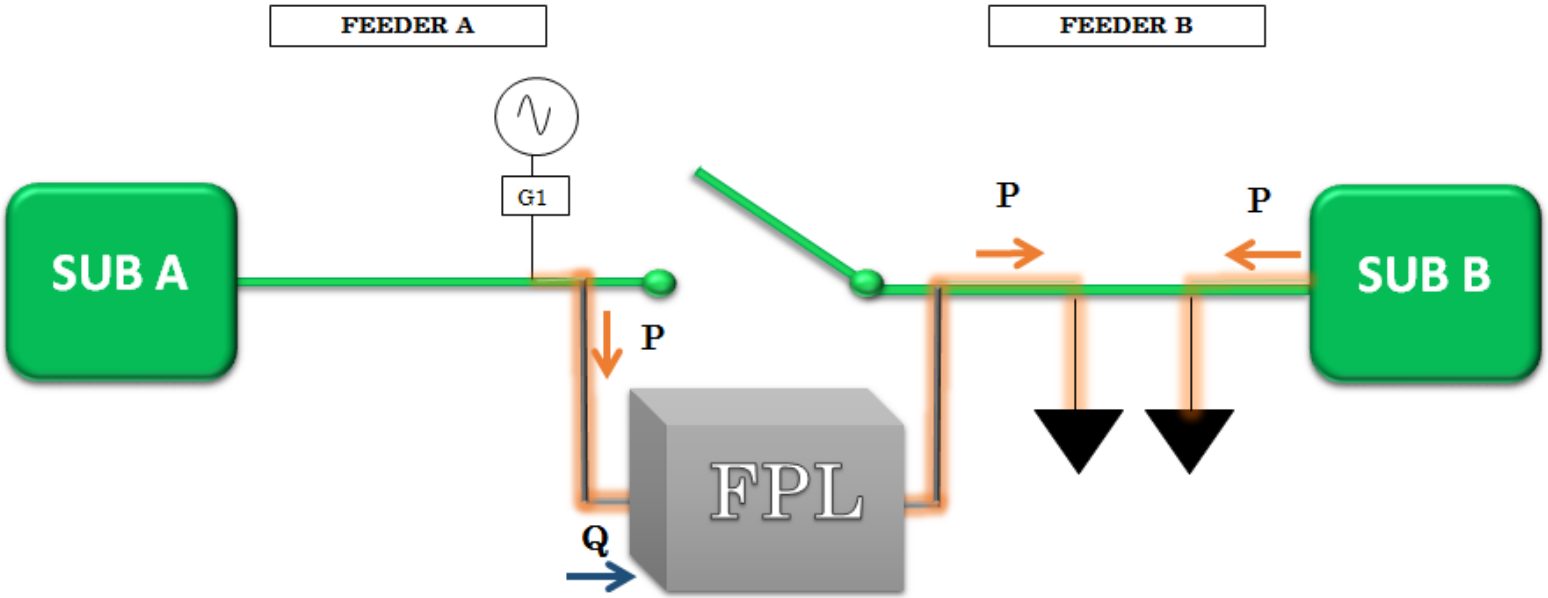


Figure 7: Thermal and voltage constraints preventing network connections.

Network Equilibrium – Flexible Power Link



- FPL transfers P from feeder A to feeder B. Removes thermal constraint!
- FPL provides Q support on feeder A. Removes V constraint!
- G1 can connect!

Figure 8: Thermal and voltage constraints removed by FPL.

Network Equilibrium – Flexible Power Link

- Back-to-back voltage source converter manufactured by ABB.
- Interconnecting two different Grid Groups.
- Connected across a 33 kV Normal Open Point.

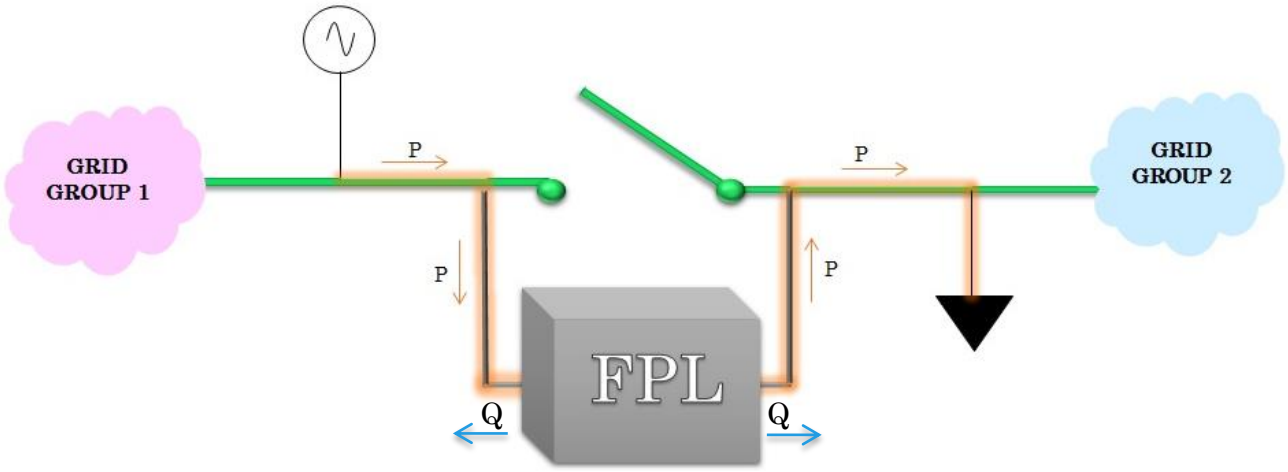


Figure 9: Flexible Power Link operation

Network Equilibrium – Flexible Power Link

- External Control System developed independently.

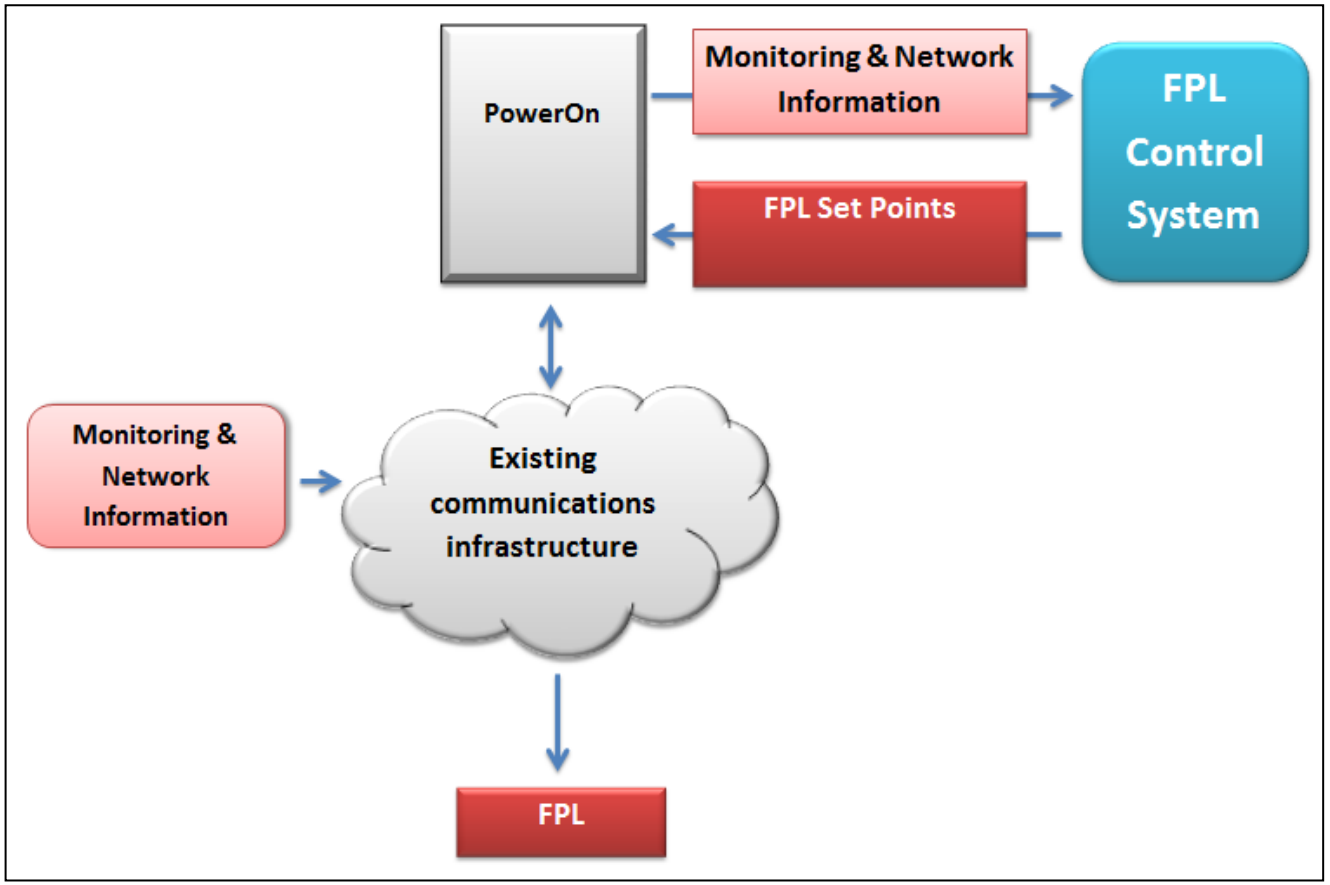


Figure 9: FPL Control System Architecture

Network Equilibrium – Flexible Power Link

What we have done so far

- Selected the site.
- Now in detailed design phase.
- Working with WPD's Engineering Design and Primary System Design and Projects teams on system integration design work.
- Contract negotiations for FPL Control System.

Network Equilibrium – Flexible Power Link

Next Steps

- Design complete by Q4 2016.
- Testing preparations complete by Q2 2017.
- FPL delivered on site Q3 2017.
- FPL commissioned and energised by Q1 2018.
- FPL Control System delivered by Q3 2017.

Network Equilibrium – What we learned

Advanced Planning Tool

Inconsistencies in historic SCADA data – Systematic approach in management of network monitoring information is required.

Manual management of network information should be minimised.

Production of network models using GIS information.

Network Equilibrium – What we learned

Advanced Planning Tool

- **Network model maintenance – critical for BAU roll out.**
- **Methodology for running power system analysis in large network model.**
- **User engagement at all stages is very important when developing a new tool.**

Network Equilibrium – What we learned

System Voltage Optimisation

- **Methodology for mapping SVO network model to Analogues collected by NMS important during model development.**
- **Knowledge on ICCP links.**
- **Involvement of different parts of the business very important for successful delivery.**

Network Equilibrium – What we learned

System Voltage Optimisation

Extracting a part of the 11kV network is challenging – high interconnectivity.

Synchronisation of SVO with NMS – coordinated model updates necessary.

Existing relays need replacement for fine voltage control.

Network Equilibrium – What we learned

Flexible Power Link

- More advanced planning tools are required for FPL site selection.
- Space availability usually limited at existing substations.
- External Control System is proposed for the FPL device at 33 and 11kV.

Summary

- Network Equilibrium is one of the projects forming our innovation strategy.

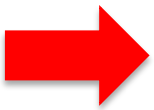
- Network Equilibrium – Aims to improve network power flows, voltage profiles and develop new planning tools.

To facilitate the integration of more LCTs in our network.

- The project consists of 3 techniques.

Summary

- VLA – Could we widen the voltage limits to release network capacity?



No knowledge on rationale behind existing limits.
Statutory voltage limits constrain network capacity.

Study complete. Suggestions provided for statutory voltage and step change limit amendments in 33kV and 11kV networks. Further consultation to consider other parts of the UK and regulatory aspects.

Summary

- APT – Planning tool with advanced functionalities.

Existing planning tools only consider very conservative scenarios.

APT will provide better understanding of real network operation and will support:

1. Analysis using historic time-series information.
2. Analysis using typical demand and generation profiles.
3. Short-term forecasting of demand and generation using weather data.
4. Modelling and planning of SVO and FPL.
5. Evaluation of network capacity.

Summary

- APT – Planning tool with advanced functionalities.

Development of the tool is in progress.

Current version includes plugin modelling and analysis using typical and forecasted demand and generation.

Trial of the tool to commence in Q3 2017.

Summary

- SVO – Real time, dynamic voltage control.

Existing voltage control systems not suitable for modern networks and limit available network capacity.

SVO will adjust the target voltages at 8 BSPs and 8 Primaries in real time, based on the operating conditions.

It will communicate with WPD's NMS to receive network monitoring information and send the optimised target voltage settings.

Summary

- SVO – Real time, dynamic voltage control.

→ Sites selected and site work identified and planned.

→ Design work in progress.

→ System to go live by Q4 2017.

Summary

- FPL – Converter for voltage support and power flow control, connecting two independent networks.

New connections limited by both voltage and thermal constraints.

FPL will remove network constraints by providing voltage support and transferring power to neighbouring network with spare capacity.

It will be controlled by an external system that has view of the network in real time.

Summary

- FPL – Converter for voltage support and power flow control, connecting two independent networks.

- Site selected.
- Detailed design of FPL in progress.
- Contract negotiations for FPL Control System.
- FPL commissioned and energised by Q1 2018.
- FPL Control System delivered by Q3 2017.

Network Equilibrium

Improve the network voltages.

Control the network power flows.

Understand and plan networks better.

To make the most of existing network and enable more Low Carbon Technologies to connect.

THANKS FOR LISTENING

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