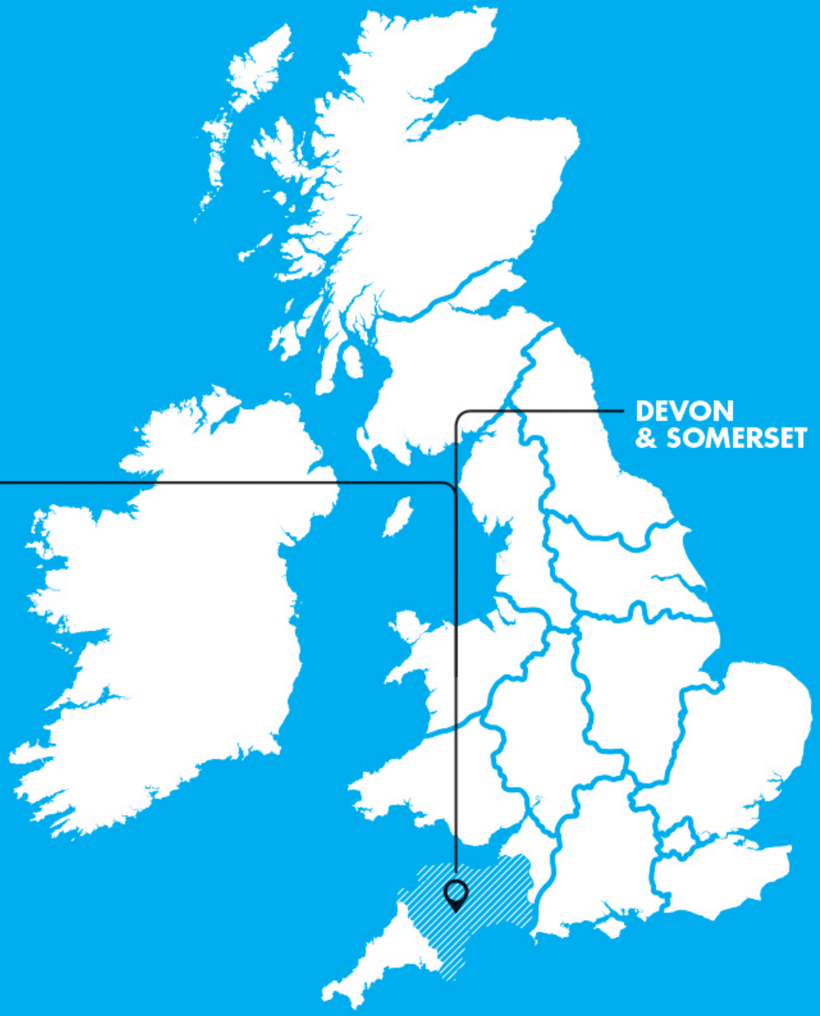
WESTERN POWER DISTRIBUTION

NETWORK EQUILIBRIUM

BALANCING GENERATION AND DEMAND



Network Equilibrium

SVO Workshop 27.01.2016

LCN Fund
Low Carbon Networks

Agenda

• Introduction	10.00 – 10.25
• Overview of Network Equilibrium	
• Detailed overview of SVO method aims	10.25 – 11.10
• Site Selection	
• SVO Technology Spectrum 5 Network Monitoring Site selection	11.10 – 12.30
• Lunch	12.30 – 13.00
• Policy and operational implications	13.00 – 13.45
• Next Steps and feedback	13.45 – 14.30

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.
- Balance voltages and power flows – Enable more Low Carbon Technologies to connect.

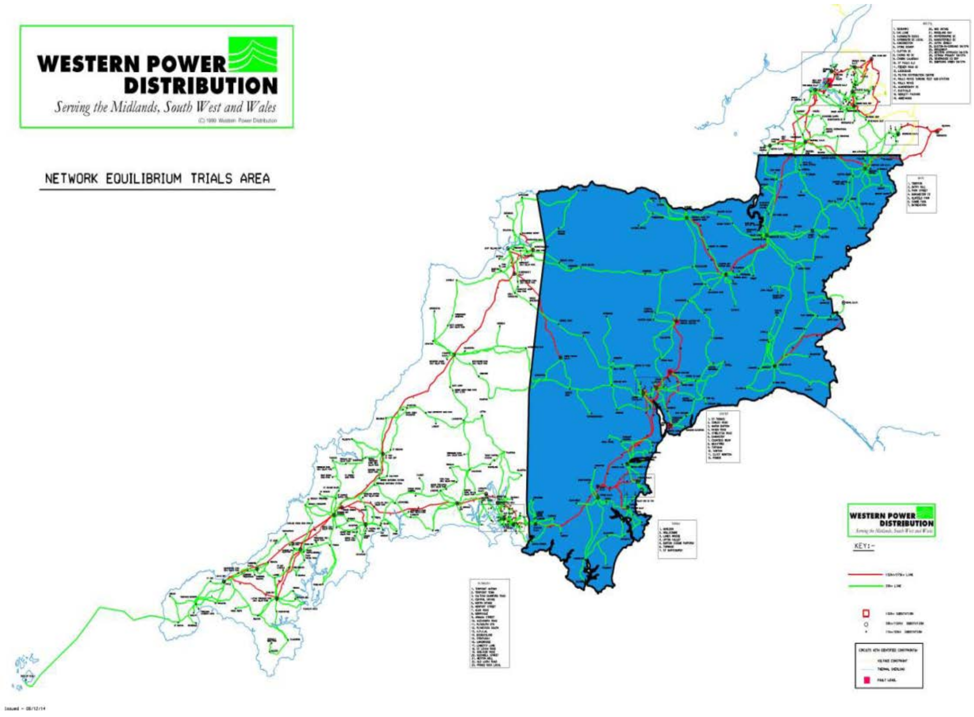


Figure 1: Network Equilibrium Project area

Network Equilibrium – The Technique Aims

EVA

Enhanced Voltage Assessment

- **Part 1:** Improve DNO planning and design tools.
- **Part 2:** Provide Industry wide recommendations for future amendments of voltage limits.

SVO

System Voltage Optimisation

- Provide technical specifications on coordinated voltage control at 11kV and 33 kV.

FPL

Flexible Power Link

- Improve network resilience.
- Balance generation and demand.
- Improve security of supply.

Method 1) Enhanced Voltage Assessment

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.

New Learning

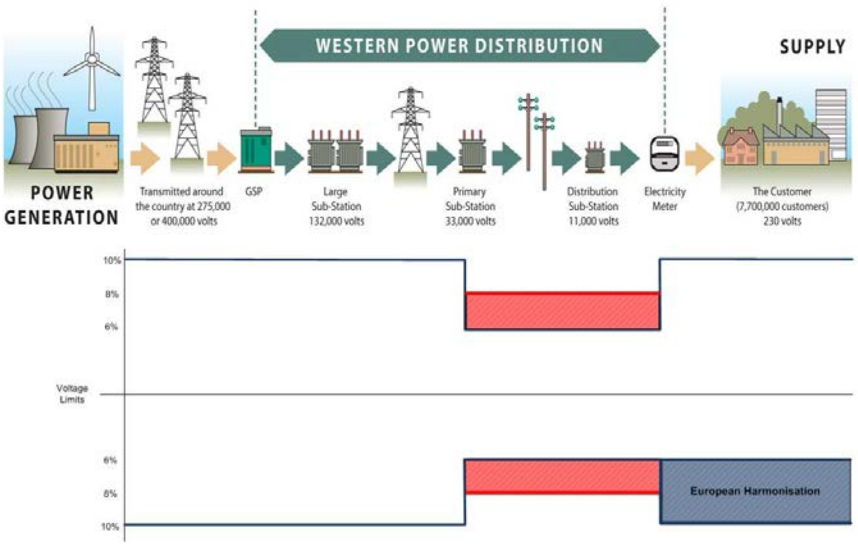
- Tool for planning and operational purposes
- Replicating innovative solutions in nodal analysis tools
- Using historic and forecasted network (and weather)data to plan and re configure networks
- Using EVA to recommend settings for Innovative solutions.

Benefits

- Unlock additional network capacity (DG and LCTs)
- Demonstrate solutions that are transferrable to other GB DNOs
- During abnormal network configuration (faults and maintenance), reduce the impact on demand and DG customers.

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

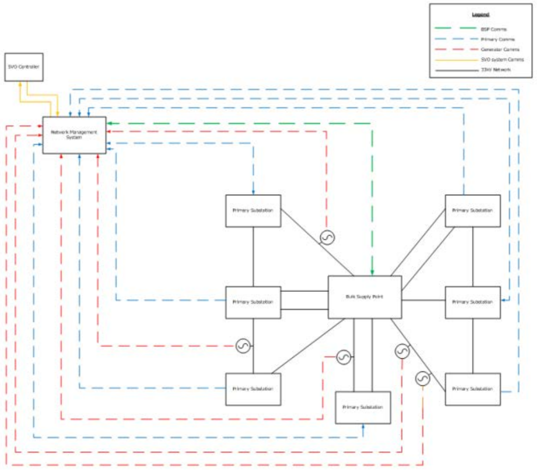
- Championing a change in operational voltage limits
- Amending voltage limits for 33kV and 11kV networks would quickly and effectively unlock additional capacity for generation and demand customers.

Method 2) System Voltage Optimisation

The SVO Method will demonstrate how novel algorithms 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.

New Learning

- Taking account of both normal and abnormal network conditions
- Operating for loss of comms & monitoring points
- Facilitating advanced controls using existing and new hardware
- Demonstrating a complete solution
- Creating guidelines that can easily be rolled out at scale across a complete licence area.



Benefits

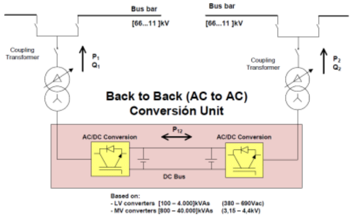
- Unlocking additional network capacity (DG and LCTs)
- Transferring the knowledge to other GB DNOs, allow them to accommodate increased levels of LCTs at scale.

Method 3) Flexible Power Link

The FPL Method will install innovative power electronic devices (back to back AC –DC units) 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.

New Learning

- Demonstrating in the UK for the first time
- Integrating into existing networks and configuring for both steady state and transient support
- Improving the system operation, reducing losses, improving system balancing and resulting in nodal voltage improvements.



Technical overview of an FPL

FPL installed in Germany for a rail application

Benefits

- Unlocking capacity of DG and new LCTs
- Avoiding the installation of new, assets
- Reducing the impact on customers under abnormal conditions
- No impact on Fault levels
- Providing learning for a technology with the right level of maturity for LCN Fund trials.

SVO – What is the problem we want to solve?

- Existing voltage control systems designed for passive, demand dominated networks.
- Static AVC settings – High target voltage to ensure voltage at end of feeder within statutory limits.
- The network has changed – traditional AVC systems impose constraints.

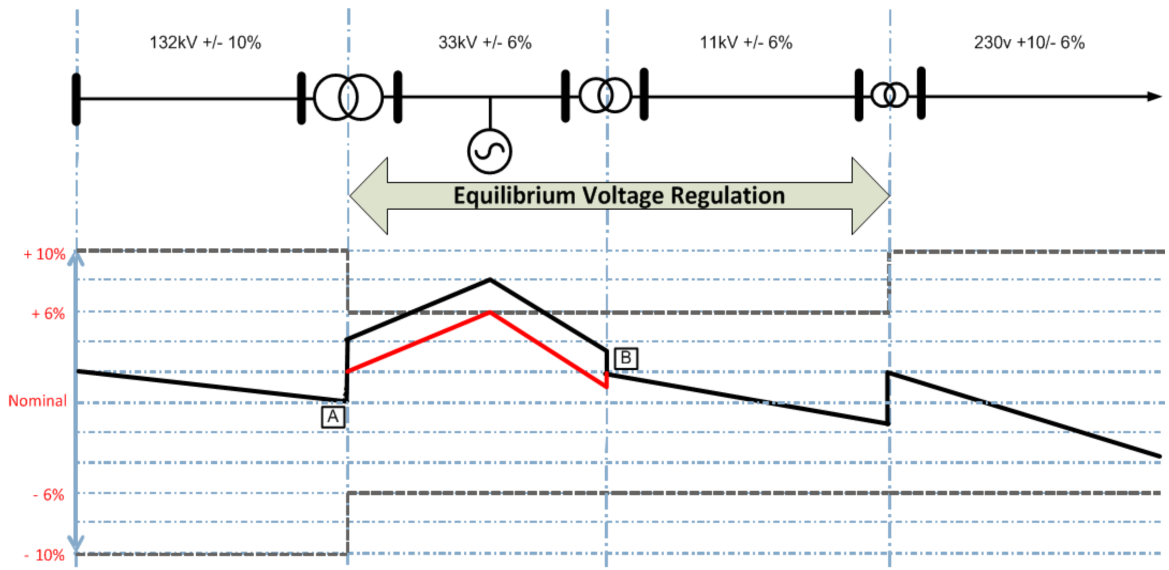


Figure 1: Equilibrium voltage control

SVO – What is the problem we want to solve?

- Embedded generation increases network voltages – Traditional, high target voltage restricts amount of generation that can be connected to our network.
- Statically reducing the target voltage not a solution – low voltage issues at times of high demand.

Dynamic network requires a dynamic voltage control system

System Voltage Optimisation – Aims

- Dynamically improve network voltage profiles by responding to real-time network conditions.
- Release network capacity through intelligent voltage control.
- Provide technical specifications on coordinated voltage control at 11kV and 33 kV.

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Network Equilibrium's System Voltage Optimisation

- Centralised system - monitors state of the network.
- Calculates and sends optimised target voltage settings to AVC relays.

Figure 2: System Voltage Optimisation operation

SVO Site Selection

- Equilibrium Trial area has 28 BSPs and around 200 Primary Substations.
- SVO to be implemented at 8 BSPs and 8 Primaries.

How do we select the best 8 locations of each?

SVO Site Selection

- **STAGE 1- Sites that would benefit the most:**

  12 BSPs with highest number of voltage constraints selected

  10 Primaries with most embedded generation selected

- **STAGE 2 – Sites that would offer valuable learning:**

  More sophisticated Power System Analysis to choose 8 of each

SVO Site Selection – Stage 2 Considerations

1. Will it be possible to change the target voltage settings?

- Power System studies to determine the minimum target voltage modification achievable at each site.

2. What is the impact of applying new AVC settings at BSPs to the surrounding network and substations?

- Power System Analysis to apply target voltage modification and understand impact on voltage control at lower voltage levels.

3. Are there any practical issues that could make the implementation of SVO challenging?

- Investigation of existing equipment at each site, space availability, health and safety.

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Consideration 1-Capability of amending the target voltage

- How much can the target voltage be increased/decreased at each candidate site?

2 scenarios

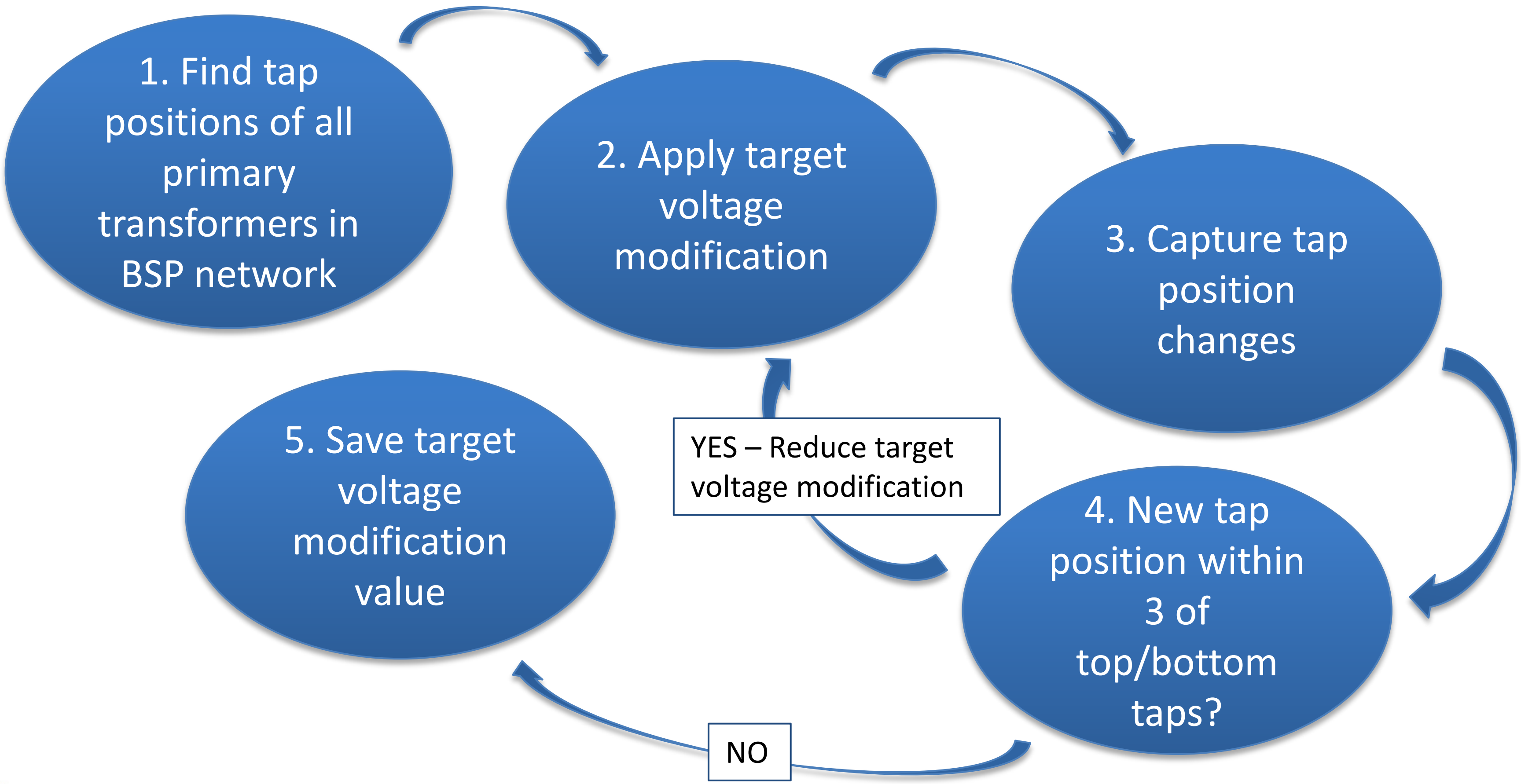
Maximum Generation
Minimum Demand

$$\boldsymbol{Target\,V\ increase} = 1.06 - maximum\_v$$

Minimum Generation
Maximum Demand

$$\boldsymbol{Target\,V\ decrease} = minimum_v - 0.94$$

Consideration 2-What is the impact of applying the derived target voltage modifications on the surrounding network?



Consideration 3 – Is the SVO installation practically challenging?

- Investigation into space availability at each site and existing equipment.

Final Selection

We knew:

1) How easy it would be to modify the target voltage at each site without limiting traditional AVC control of surrounding network.
2) How easy the SVO installation would be at each site.

Final Selection

We aimed:

1) To maximise the learning we could gain from the trials.
2) To be able to make valuable recommendations for a Business As Usual roll out of SVO.

→ **A combination of sites was selected**

Final Selection – Combination of sites

12 candidate BSPs separated into 4 categories of 3, each offering different learning.

2 chosen from each category – 1 back-up option in each

Category	Description	Learning
Category A	Significant target voltage adjustment.	Testing of full SVO system.
Category B	Good target voltage adjustment.	Improvement at sites where static AVC changes are possible.
Category C	Limited target voltage adjustment.	Understand how restrictive existing planning procedures are.
Category D	Extremely limited target voltage adjustment.	Release of capacity at heavily constrained networks with SVO.

Final Selection – Combination of sites

10 candidate Primaries separated into 2 categories of 5, each offering different learning.

4 chosen from each category – 1 back-up option in each in case a site is rejected for practical reasons.

Category	Description	Learning
Category 1	Good target voltage adjustment.	Testing of full SVO system.
Category 2	Challenging target voltage adjustment.	Release of capacity at heavily constrained networks with SVO.

Summary

- Static voltage control limits the capacity of the distribution network.
- SVO is a dynamic voltage control system that aims to release network capacity by optimising voltage profiles.
- Assesses state of network in real time, calculates and sends optimal settings to AVC relays.

Conclusions from analysis

- Impact of target voltage increase/decrease on transformer tap positions heavily dependent on network's generation/demand and their distribution.

  → Confirms need for a fully dynamic voltage control system that can asses network state in real-time.

- SVO at BSP-Primary "pairs" challenging if they have opposite objectives.

  → Confirms need for better planning tools to ensure that SVO is not installed at restricted networks.

- Important to understand the window available for target voltage modification in the planning stages of a dynamic voltage control system.

Summary

We wanted to:

1. Ensure we are able to capture as much learning as possible from the SVO trials.
2. Be able to provide valuable recommendations for a Business As Usual rollout of SVO in any network.

→ **Carefully planned Site Selection Process**

Summary

We chose 8 BSPs and 8 Primaries:

- With different target voltage modification capabilities by separating them into different categories.
- Back up options for each BSP and Primary category in case sites are rejected for practical reasons.

Summary

In the process:

- Got better understanding of interaction between BSP and Primary voltage control systems.
- Verified the need for an intelligent, real time system.

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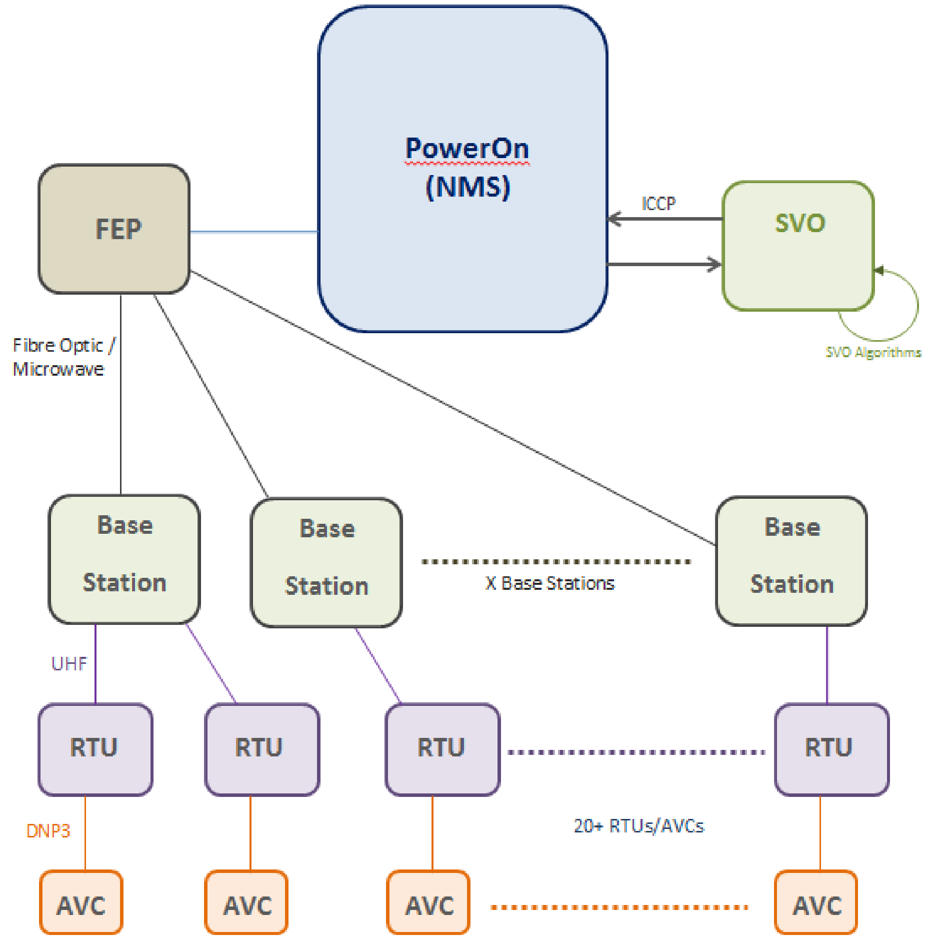
Questions?

SVO Technology

- System Overview
- Spectrum Power 5 (Siemens)
- Voltage Control
- Network Monitoring

SVO Technology - System Overview



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SVO Technology - System Overview

- Move from static voltage set-points to dynamic system voltage control. Primarily for additional load / generation connectivity but could also be optimised for losses

"**Fine Control**" Specific voltage, to the closest 0.1kV, calculated by Spectrum 5 to optimise the network voltage for the situation a voltage regulating relay can accept individual voltage values.

"**Settings Control**" Determination of a voltage setting, where a voltage regulating relay has a select number of voltage setting points it can accept. Spectrum 5 is to be programmed with the available relay voltage settings and determine the most suitable.

SVO Technology - Spectrum Power 5

- Siemens Description

An intelligent centralised Volt-Var Control (VVC) is an important DMS application for dealing with the complexity of the voltage and reactive power control in a modern distribution system. This complexity usually limits decentralised capabilities of local automatic controllers that typically supervise voltage controllers and switched capacitors.

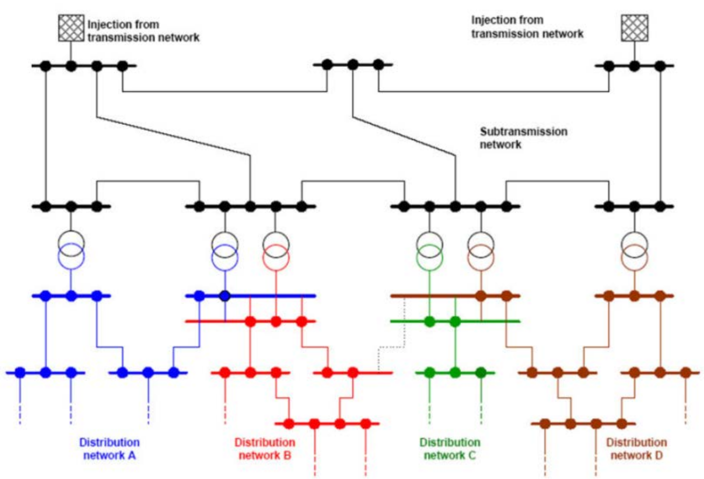
VVC application is based on the master station (control centre) as opposed to the substation. The master station-based VVC application allows the following capabilities:

- *Local controllers can respond to changing system conditions*
- *Various VVC objectives can be utilized*
- *VVC is optimizing at subsystem level, not at local level*

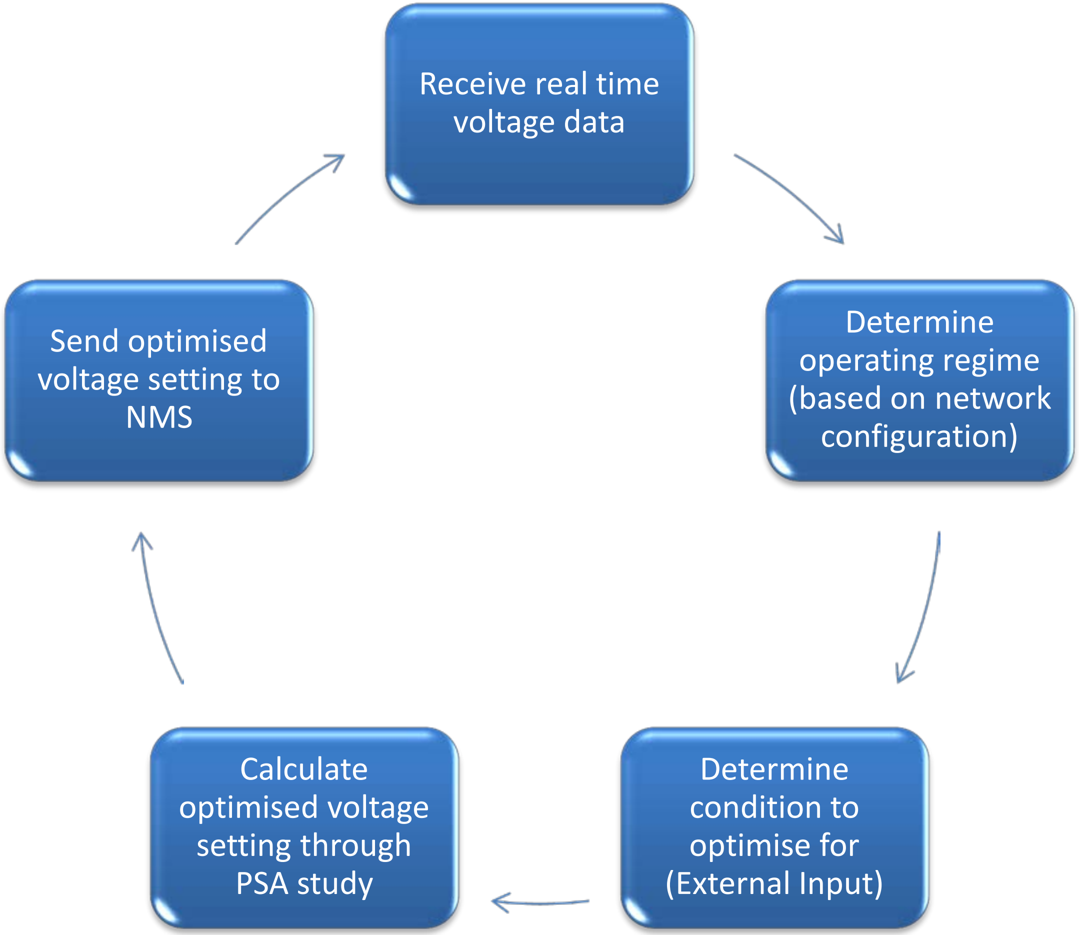
SVO Technology - Spectrum Power 5

- WPD Description

System that, in near real-time, executes network studies (Power System Analysis) based on near real-time voltage data from the network and detailed network parameter details. Decisions can be made to optimise the voltage through changing the voltage set-point either as ***fine control*** *or* ***setting control*** *applications.*



SVO Technology - Spectrum Power 5



Voltage Control

What we do today:

- Standard AVC settings control the network voltage to a set voltage within a percentage tolerance 365 days a year (except for non-standard running arrangements)

Voltage Control

What we are going to do:

- Investigate the active control of voltage to benefit generation connection capacity, where previously voltage limits have been a key restriction

Voltage Control

How are we going to do it:

- Adapt existing relays on site
- Change existing relays on site

MR Tapcon ISM Relay

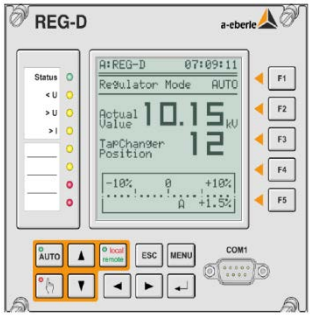
MicroTapp Relay

Fundamentals SuperTapp SG Relay

AVE5 Relay

MVGC01 Relay

KVGC202 Relay

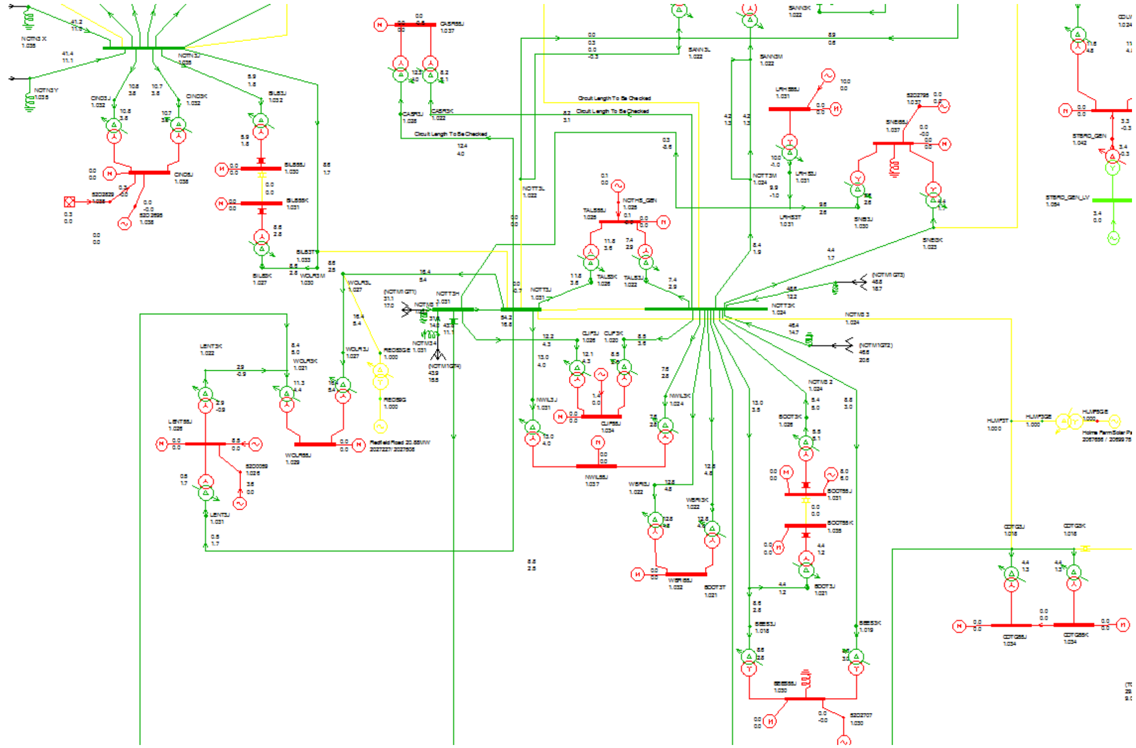


A-Eberle REG-D Relay

Network Monitoring

What do we need to monitor:

- 33kV Tx Busbar
- 33kV Remote Points
- Key 33kV Load and Gen
- 11kV at Primaries



Example 33kV Network

Network Monitoring

How will we monitor:

- 33kV VTs
- 132/33kV Tx Tapchanger positions
- 33/11kV Tx Tapchanger positions
- Key 33kV Load and Gen
- 11kV VTs
- LV Transformer Monitoring

Network Monitoring

Optimal amount of monitoring:

- High Penetration
  - All Points of Transformation
  - All Remote Ends
  - All Generation
- Medium Penetration
  - SVO Site Point of Transformation
  - Key Remote Ends
  - Key Generation
- Low Penetration
  - SVO Site Point of Transformation
  - Most Remote End
  - Key Generation

Questions?

Lunch

Policies and Operation

- Introduction of New Relays
- Application and Operation
  - Safeguarding against extreme voltages
  - Consideration of Wider network issues
  - Number of Voltage change decisions a day
  - Return to ‘normal’ conditions
  - Different Gens need different attributable settings
- Tapchanger maintenance
  - Time based to operation based maintenance

Next Steps

- SDRC 1 – 3 Design Methodology
  - EVA Jan 2016
  - SVO Feb 2016
  - FPL March 2016
- New Relay approvals on going
- SVO Kick Off & site selection
  - From Mid-Feb 2016
- FPL Tender decision
  - March 2016

Proposed Timeline

- SVO build
  - First site Design from 1st March 2016
  - Rolling program throughout 2016 & 2017
- FPL build
  - Contracted by end March 2016
  - FAT testing early summer 2017
  - Deliver to site and commissioned by end 2017

Any Final Questions?