WESTERN POWER DISTRIBUTION

FLEXDGRID

HEAT AND POWER FOR BIRMINGHAM

DNO Workshop on the Implementation of Enhanced Fault Level Assessment Processes

Wednesday 23rd October 2013

LCN Fund Low Carbon Networks

THE UNIVERSITY OF WARWICK

PARSONS BRINCKERHOFF

Introduction

- House-keeping
- Agenda
- Round table introductions
- Workshop aims

Agenda

10:00 – 10:30	**Arrival – Refreshments and Networking**
10:30 – 10:50	Round table introductions to include delegates' background in fault level modelling
10:50 – 11:00	Overview of FlexDGrid and the purpose of the workshop
11:00 – 11:30	Presentation 1 – Topic Focus: Dissemination of SDRC-1 (Enhanced fault level assessment processes)
11:30 – 12:05	Presentation 2 – Topic Focus: Monitoring and mitigation of fault level
12:05 – 12:30	Q&A session
12:30 – 13:15	Lunch and Networking
13:15 – 14:10	Discussion session 1: Monitoring of fault level and impact on connection applications
14:10 – 14:20	Break
14:20 – 15:15	Discussion session 2: Modelling of fault current limiters and impact on connection applications
15:15 – 15:30	Summary of workshop results and next steps
15:30	Close

Round Table Introductions

DNO	Name	Job Title
WPD	Jonathan Berry	Innovation Engineer
WPD (Parsons Brinckerhoff)	Ali Kazerooni	FlexDGrid Modelling Lead
WPD (Parsons Brinckerhoff)	Neil Murdoch	FlexDGrid Distribution Lead
WPD (Parsons Brinckerhoff)	Samuel Jupe	FlexDGrid EFLA Lead
WPD (Parsons Brinckerhoff)	Stewart Urquhart	Assistant Engineer
UKPN	Ian Cooper	Senior Technology Transfer Engineer
UKPN	Bill Reeves	Distribution Planning Engineer
UKPN	Musa Shah	Distribution Planning Engineer
SSE	David Mobsby	Operational Planning Engineer
SSE	Tawanda Chitifa	R&D Project Manager
SSE	Will Monnaie	System Planning Engineer
SPEN	Malcolm Bebbington	Senior Design Engineer
NPG	Dr. Roshan Bhattarai	System Planning Engineer

FlexDGrid – What and Why

What are we doing?

Understanding, Managing and Reducing the Fault Level on an electricity network

Why are we doing it?

Facilitating the early and cost effective integration of Low Carbon generation

Why are we doing it now?

Supporting the Carbon Plan – Connection of generation to the grid and development of heat networks – reducing carbon emissions

FlexDGrid - Overview

Three integrated Methods leading to quicker and cost effective HV customer connections through a timely step change in the enhanced understanding, management and mitigation of distribution network fault level

Enhanced Assessment

- Enhanced network models
- Detailed understanding of network Fault Level

Management

- Monitoring Fault Level (Steady-state)
- Measuring Fault Level (Faulted-state)
- Verify/Update network models

Mitigation

- Reduction of system Fault Level
- Utilised from output of Management

Each Method can be applied on its own whilst the integration of the three Methods combined will provide a system level solution to facilitate the connection of additional generation

FlexDGrid Explained – Method Alpha

The Enhanced Fault Level Assessment Method will provide refined Fault Level analysis techniques to understand the areas of the network that are likely to exhibit Fault Level issues. This will be used to provide customers with more accurate and refined network connection offers

Problem
- Existing models built on lots of network assumptions
- Modelling uncertainty providing reserved outputs

Solution
- Provide greater network model detail and granularity
- Feed in up-to-date network arrangement and connection data

Benefit
- Increased certainty of network model accuracy
- Reduced modelling uncertainty
- Release of DG connection capacity

FlexDGrid Explained – Method Beta

The Real-time Management Method will enable accurate Fault Level data to be gathered for various network arrangements. This will be used to verify the Fault Level assessed through the Trial of Enhanced Fault Level Assessment processes

Problem

- Currently no capability to monitor Fault Level
- Essential safety margin applied due to lack of network information

Solution

- Monitor Fault Level using new device
- Feed monitored and measured Fault Level data in to enhanced network model
- Manage network using monitored and modelled data

Benefit

- Increased knowledge of networks' Fault Level
- Reduction of required safety margin
- Release of DG connection capacity

FlexDGrid Explained – Method Gamma

The Fault Level Mitigation Method will install technologies in to substations which currently exhibit Fault Level issues and where new connections are expected to cause an increase in fault currents. This Method adds Fault Level capacity by reducing fault currents

Problem

- Current Fault Level reduction solutions are costly and take a long time
- Existing solutions have limited reduction capability / no reduction but ability to accommodate more Fault Level

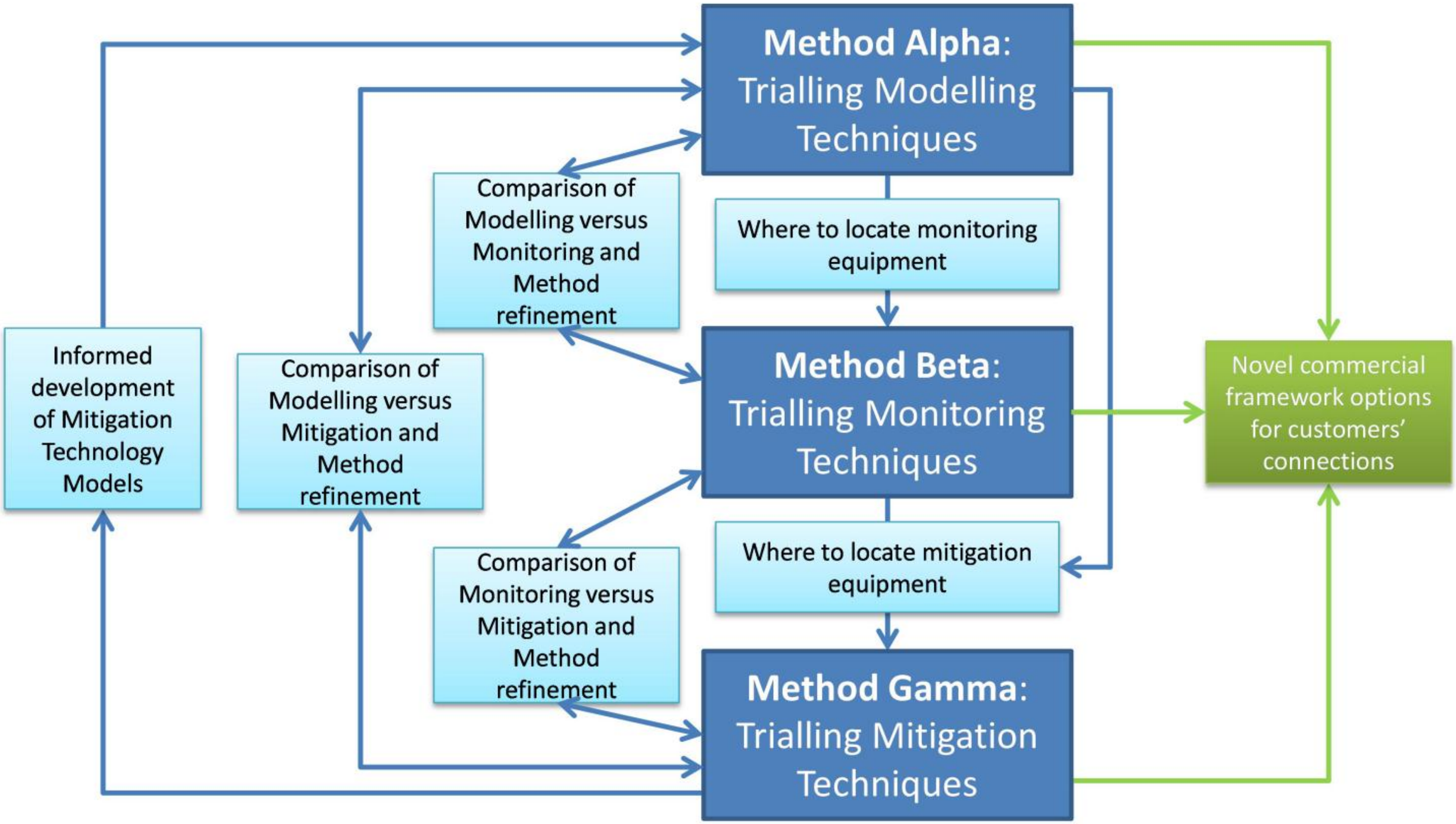
Solution

- Installation of new technologies that have been tested in a laboratory or in network isolation

Benefit

- Reduced cost of connection to all users
- Minimise time to connect generation
- Fault Level headroom is maximised

Integrated Methods and Expected Learning



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Presentation 1 – Topic Focus:

Method Alpha: Dissemination of SDRC-1 (Specifying enhanced fault level assessment processes)

Samuel Jupe MEng PhD CEng MIET

Senior Engineer, Parsons Brinckerhoff

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FlexDGrid – Method Alpha

Three integrated Methods leading to quicker and cost effective HV customer connections through a timely step change in the enhanced understanding, management and mitigation of distribution network fault level

Enhanced Assessment

- Enhanced network models
- Detailed understanding of network Fault Level

Management

- Monitoring Fault Level (Steady-state)
- Measuring Fault Level (Faulted-state)
- Verify/Update network models

Mitigation

- Reduction of system Fault Level
- Utilised from output of Management

Method Alpha: Enhanced fault level assessment processes

1. Baseline the consistency of application of present fault level assessment methods
2. Explore assumptions and carry out a sensitivity analysis of standard fault level calculation methods
3. Increasing the frequency and granularity of fault level assessments
4. Design and deployment of fault level measurement and monitoring technologies
5. Design and deployment of fault level mitigation technologies
6. Connection offers based on novel commercial frameworks

Emerging learning: DNO Questionnaire Conclusions

1. Engineering Recommendation G74 requires clarifications on its application:
   a) Guidance on new forms of generation
   b) Modelling of aggregated loads
   c) Validity of general load contribution

2. Sensitivity analysis would provide useful learning

3. Open source database of generation / motor plant types would be beneficial

Emerging learning: DNO Questionnaire Conclusions

4. Open source fault current limiter models would be of benefit to the DNO community

5. Increased frequency and granularity of fault level assessments could be beneficial but would need to outweigh increased modelling effort

6. A move to probabilistic fault level assessments was not deemed to be feasible due to ESQCR and H&S implications

7. There is a need for training processes to be documented

Emerging learning: SDRC-1 Recommendations

1. The 6 process identified and detailed in the SDRC-1 document will be followed

2. A follow-on workshop will be organised with other DNOs to feedback baseline and sensitivity analysis results

3. It is not clear how the values for general load contribution were originally derived:
   a) Load mixes and fault contributions will be investigated
   b) Introduction of fault level monitoring equipment

Emerging learning: SDRC-1 Recommendations

4. An industry-wide review of G74 should be conducted with a focus on the consistent application of G74 to HV networks

5. For training and consistency, DNOs should formally document their connection study process

6. Development of integrated EHV and HV electricity network models

7. Confirm the need to de-rate switchgear in line with CIGRE Recommendation 304

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Presentation 1 – Topic Focus:

Method Alpha:

Progress towards SDRC-4 (Implementing enhanced fault level assessment processes)

Ali Kazerooni PhD MIET

Senior Engineer, Parsons Brinckerhoff

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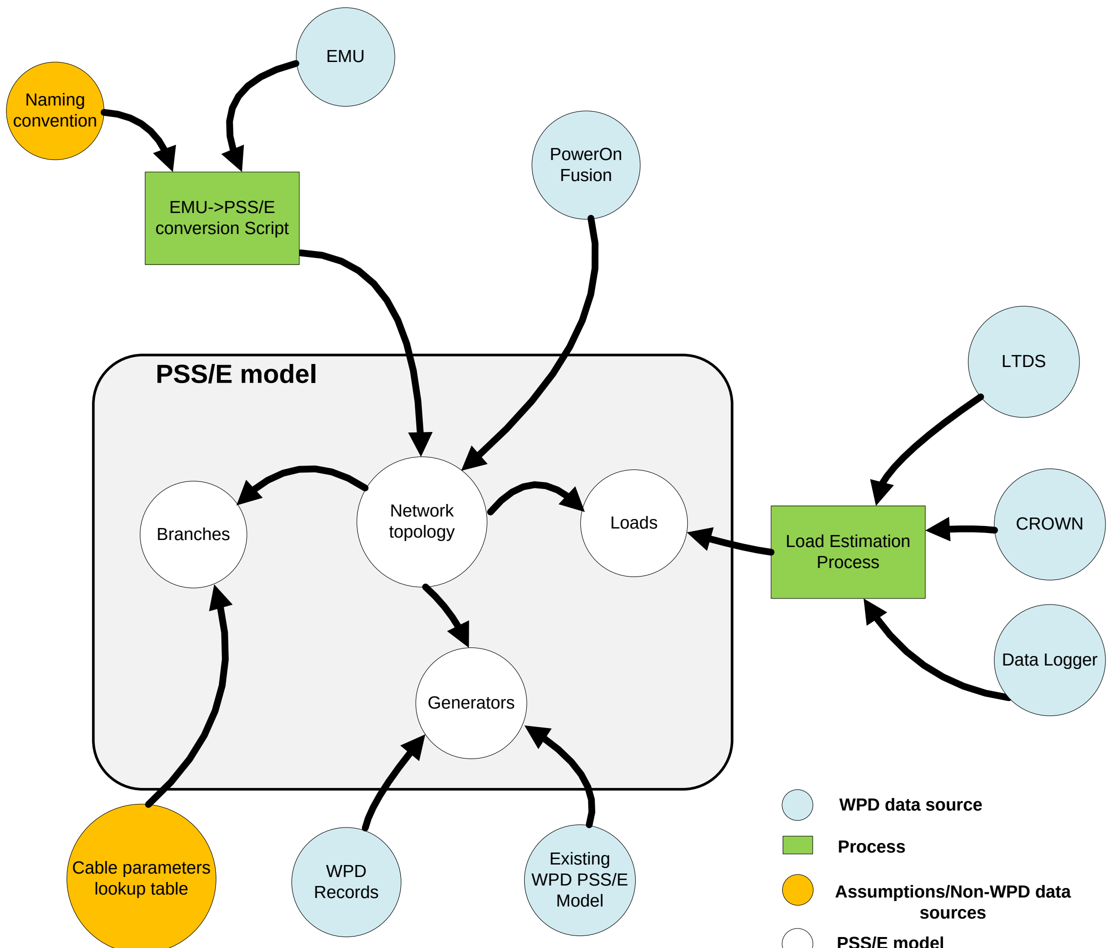
Overview

- **HV network models**
- **Fault level decrements – Heat maps**
- **Fault level sensitivity analysis**

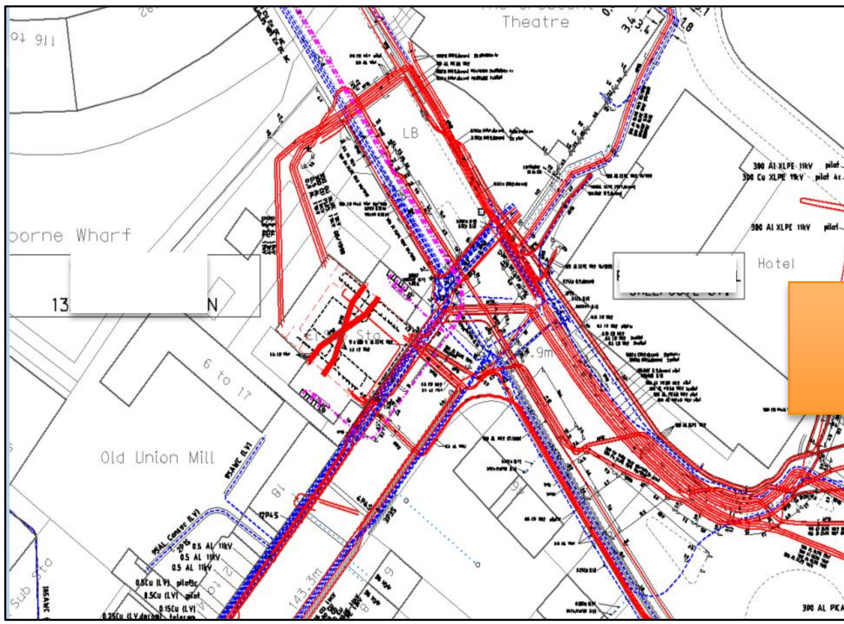
HV networks models

- Developed a methodology for creating computer models of HV networks using BaU WPD databases
- PSS/E models of HV networks of 12 primary substations in Birmingham Central Business district were developed
- Developed HV networks models can be integrated with EHV network model
- EMU (GIS database) –to- PSS/E converter Excel-based tool is developed to automate the modelling process.

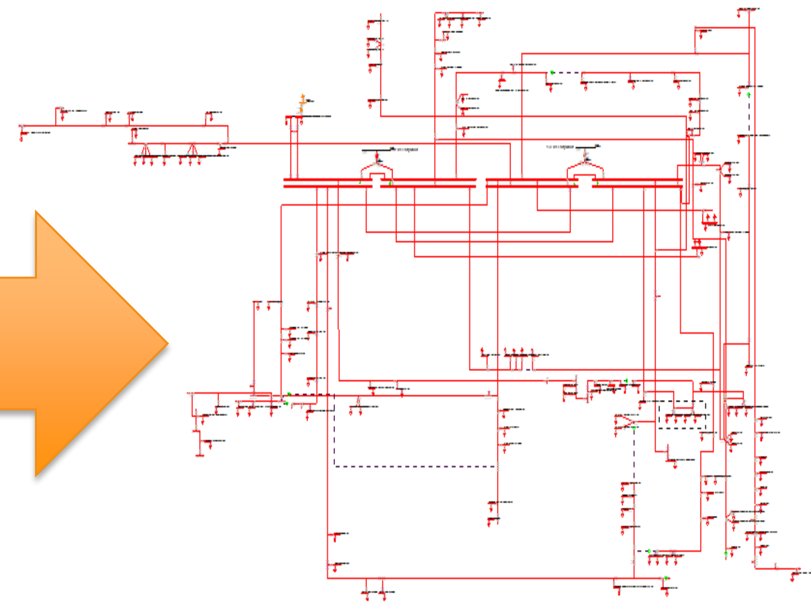
HV network models - Methodology



Modelling of HV networks – EMU to PSSE convertor



EMU

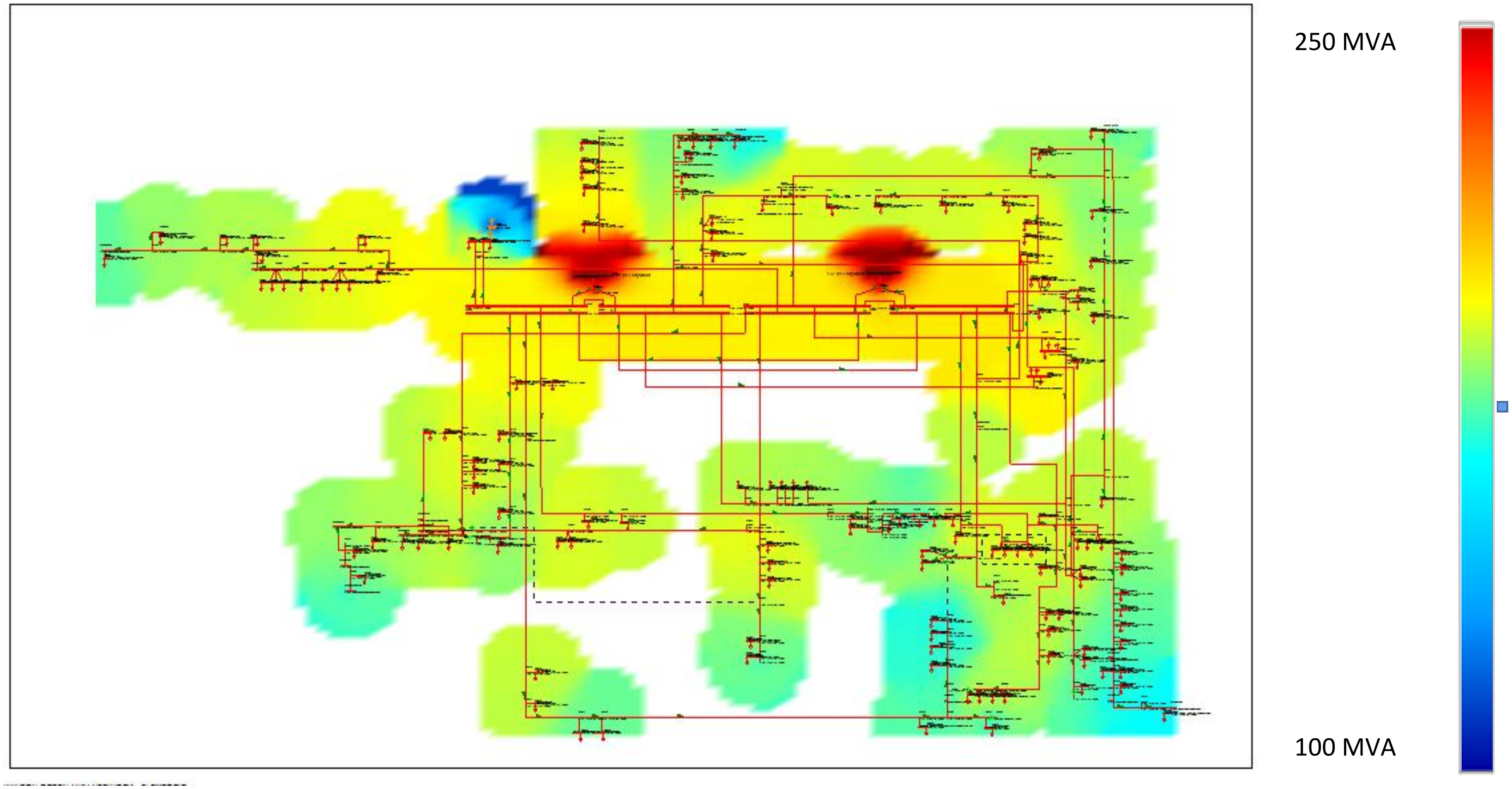


PSS/E

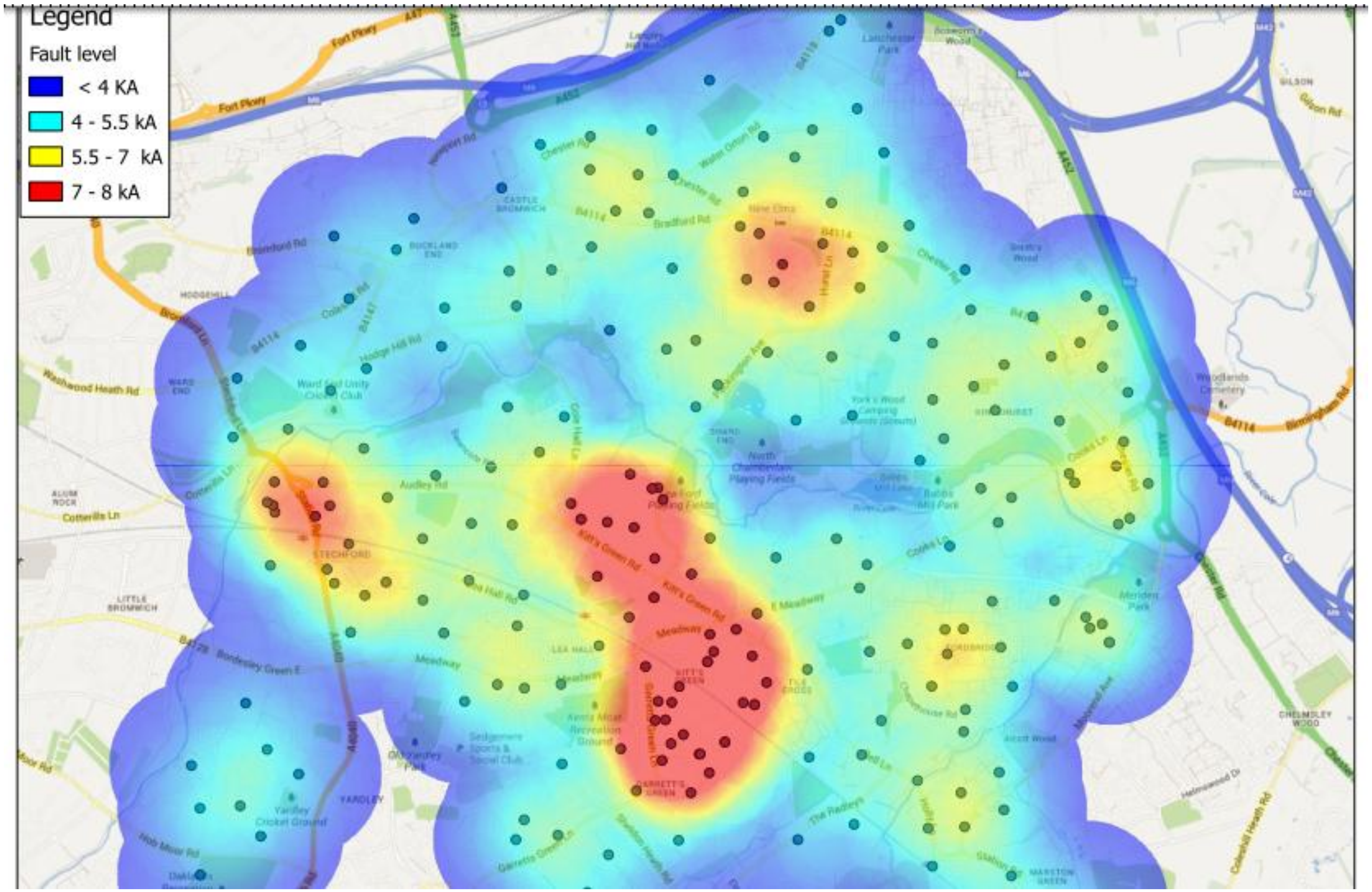
HV networks models - Benefits

- A close-to-reality calculated voltage profile
- Modelling different substation configurations
- Modelling different network arrangements - interconnectors
- Modelling generators in their actual place in the network
- Calculating fault level at distribution substations

Fault level decrement– Heat maps



Fault level decrement– Heat maps



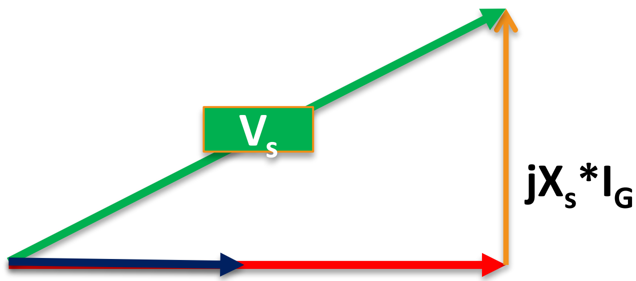
Fault level Sensitivity analysis

Sensitivity of the calculated fault level against different parameters of the electricity network model and assumptions

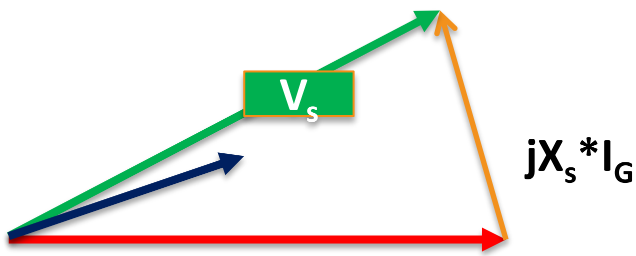
- Cable length
- Demand
- Generation power factor (PF)
- Tap position at primary substation
- General load fault infeed

FL sensitivity analysis – Generator PF

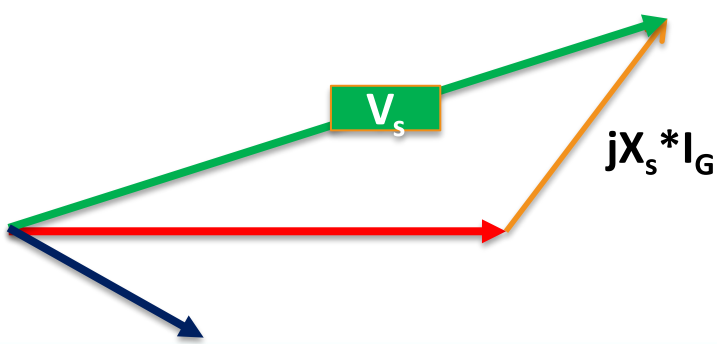
Unity PF

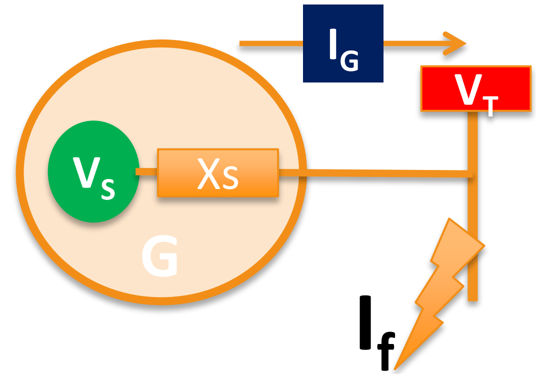


Leading PF



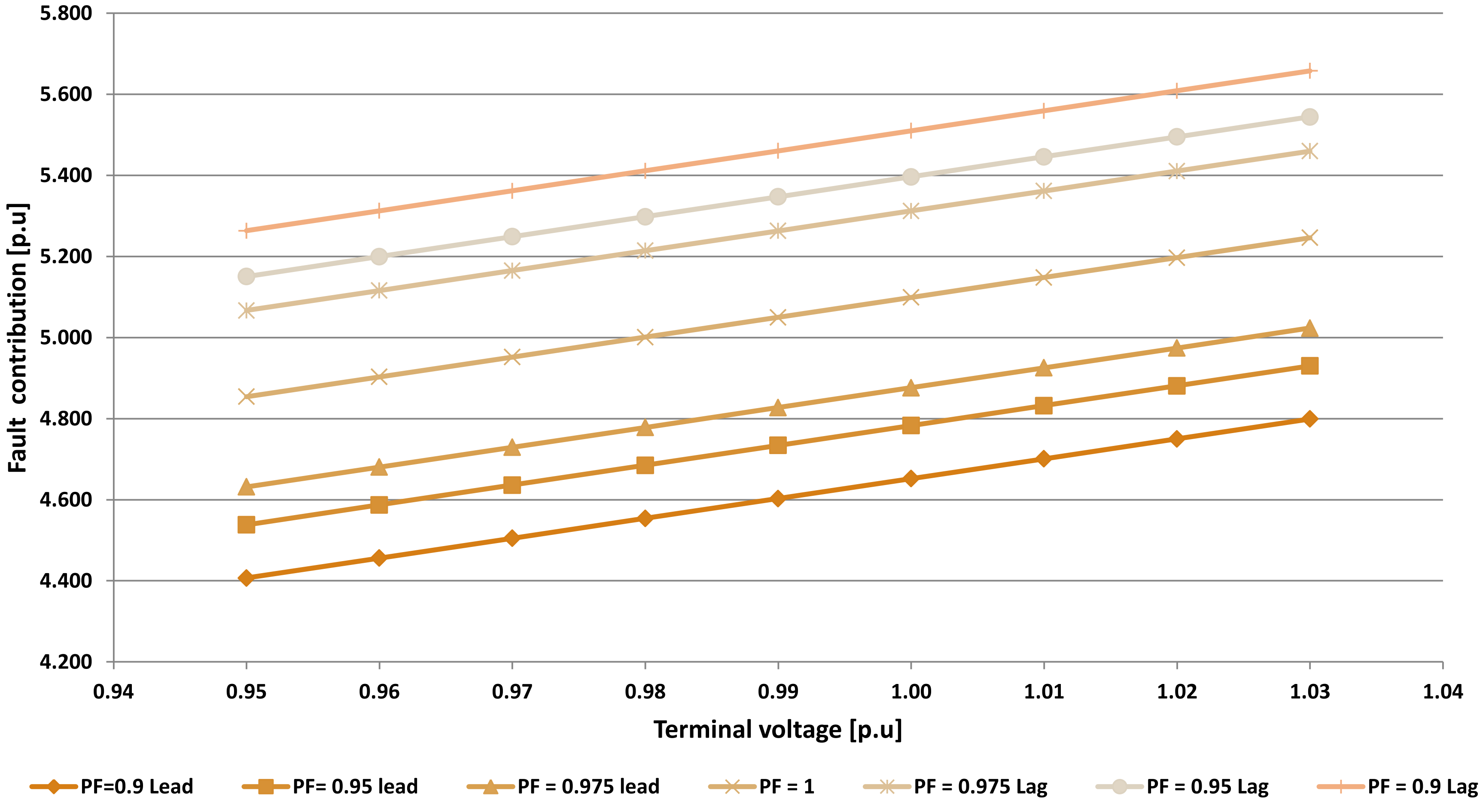
Lagging PF



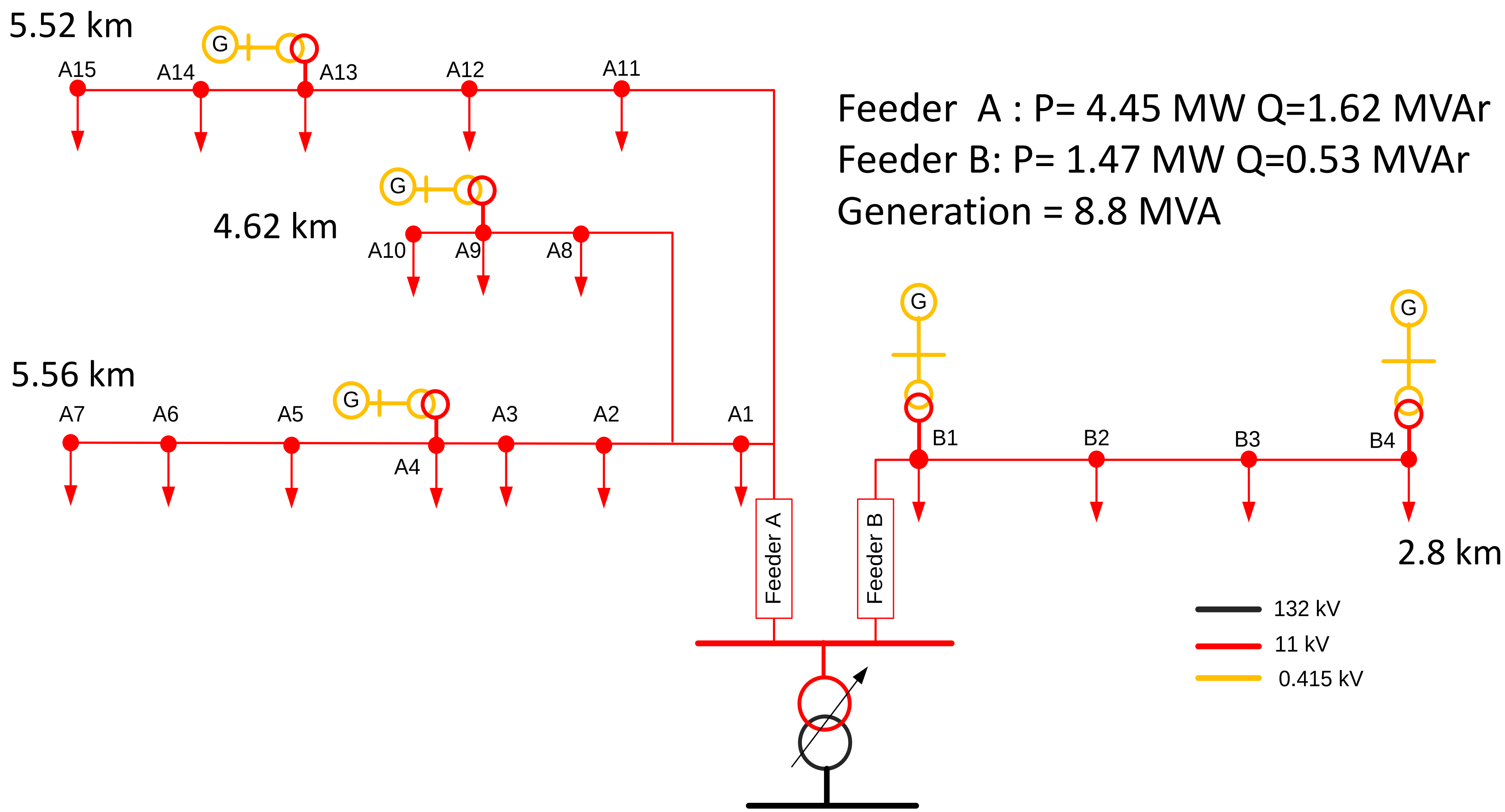


$$I_f = V_s / X_s$$

FL sensitivity analysis – Generation PF



FL Sensitivity analysis – Sample model

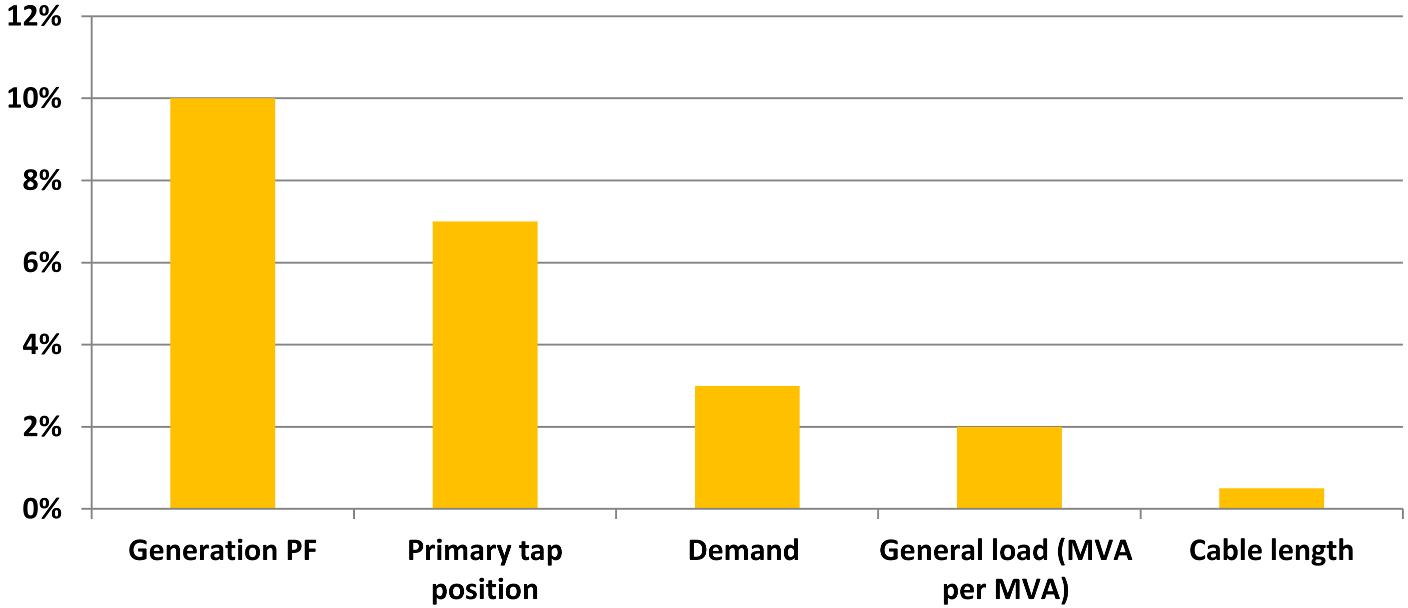


Feeder A : P= 4.45 MW Q=1.62 MVAr

Feeder B: P= 1.47 MW Q=0.53 MVAr

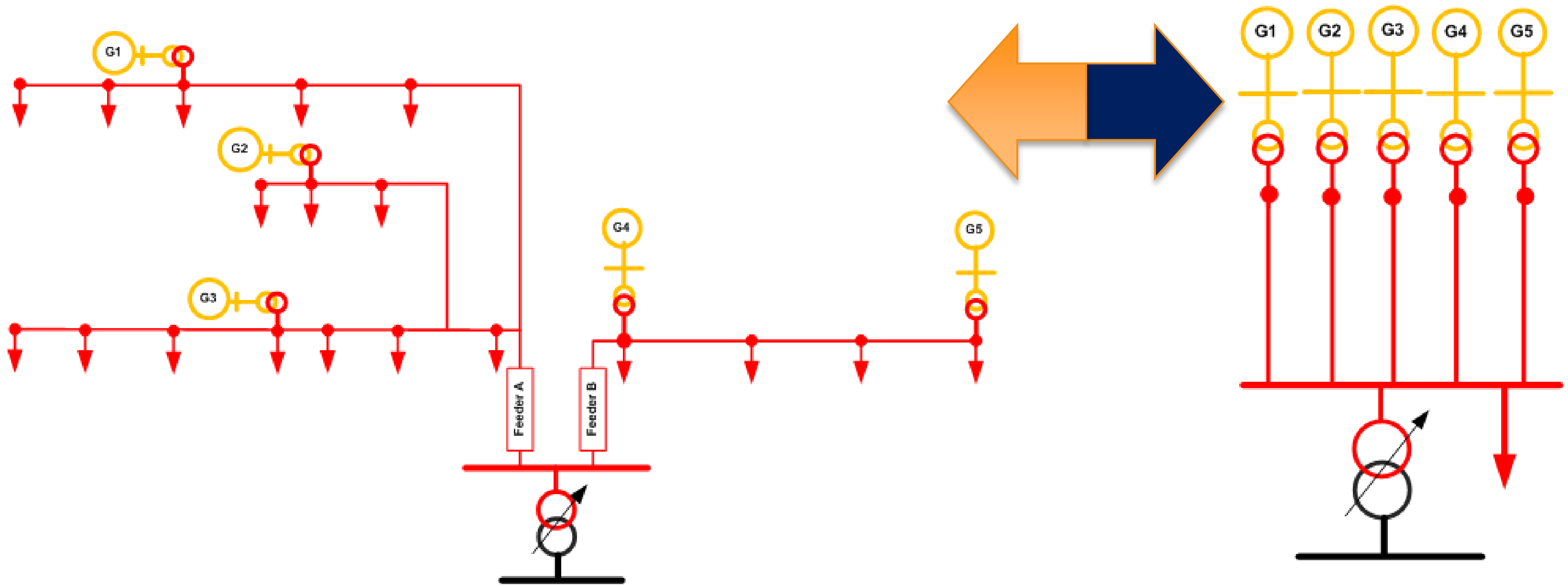
Generation = 8.8 MVA

FL Sensitivity analysis - Results



	Variation range	
Cable length	-5%	5%
Demand	-10%	10%
Generation PF	Unity, 0.95 leading, 0.95 lagging, Vset=1	
General load (MVA per MVA)	0	2
Primary tap position (voltage at HV busbars)	0.95 pu to 1.03 p.u	

FL sensitivity analysis – connection studies



	Unity PF		0.95 leading PF		Unity PF		0.95 leading PF		Gout=0	
	Make	Break	Make	Break	Make	Break	Make	Break	Make	Break
[kA]	6.76	2.50	6.26	2.23	7.13	2.60	6.71	2.43	7.05	2.57
[MVA]	128.8	47.6	119.3	42.5	135.8	49.5	127.8	46.3	134.3	49.0
Difference (%)					5.5	4.0	7.2	9.0	-	-

Conclusions

- Modelling HV network of 12 primary substations allows a close-to-reality pre-fault voltage calculation

- Heat maps enable HV planners to have a better overview of the fault level decrement in the HV networks.

- Sensitivity analysis shows that generators' operating power factor has the largest effect on calculated fault level

- For connection studies, it is recommended that generators are modelled in their actual connection point in the HV network.

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Presentation 2 – Topic Focus:

Method Beta:

Fault level monitoring and management

Samuel Jupe MEng PhD CEng MIET

Senior Engineer, Parsons Brinckerhoff

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FlexDGrid – Method Beta

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Fault level profile analysis methodology

Step 1
- Data analysis of operational configurations

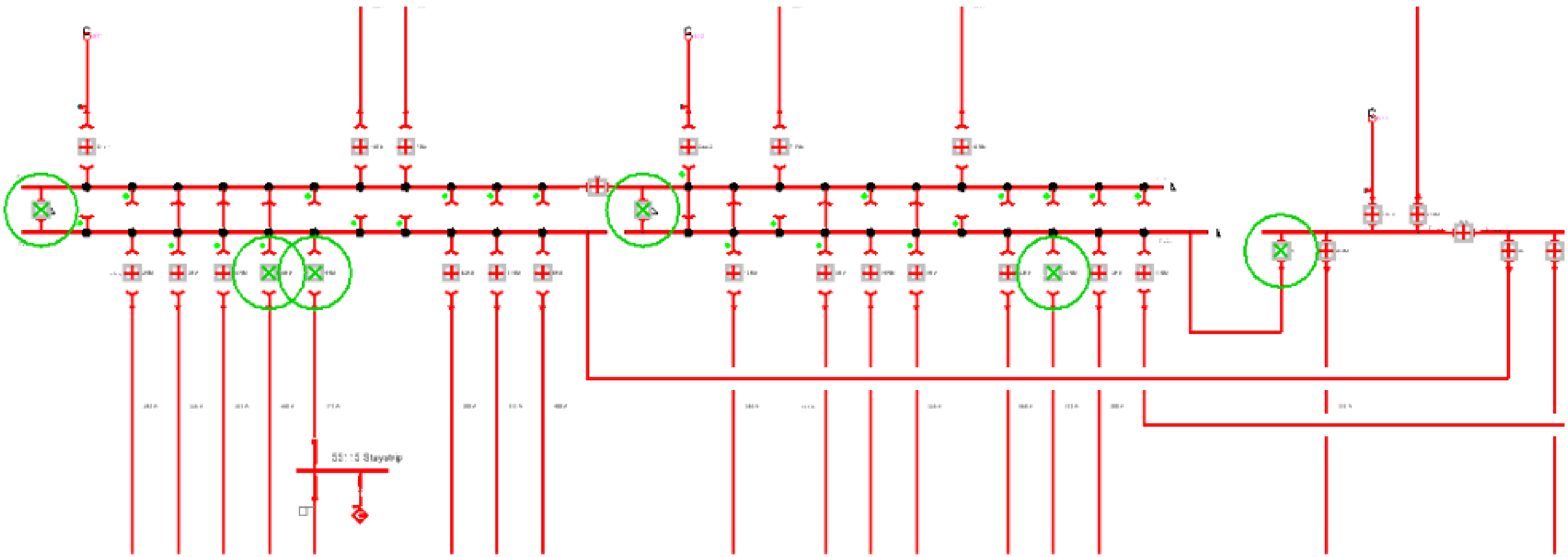
Step 2
- Run fault level studies for operational configurations
- Collate configuration states and corresponding fault level values

Step 3
- Generate time-series graph to display real-time fault level profile

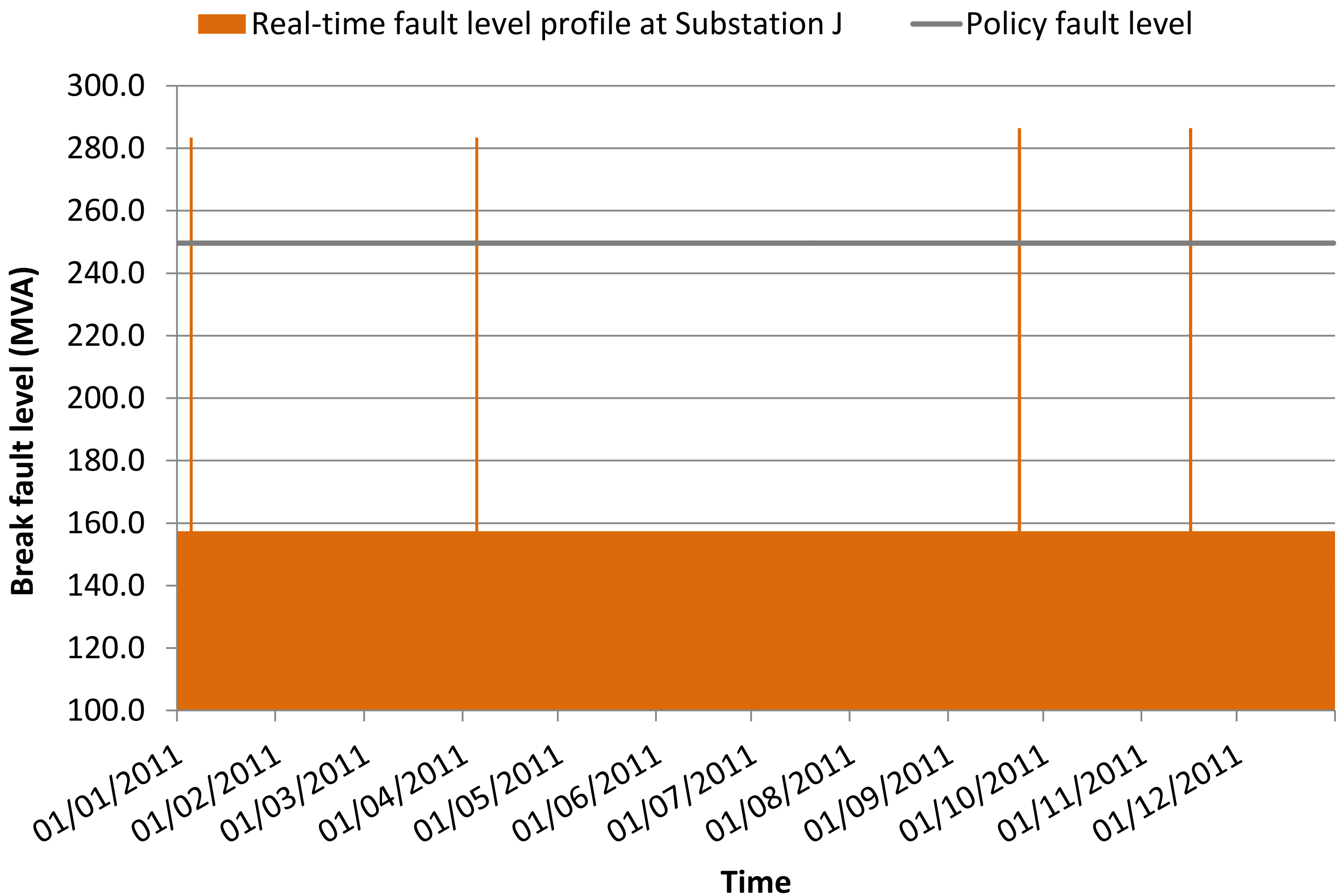
‘Connect and manage’ assumptions / caveats:

- **Generation integration into a ‘split’ network configuration**
- **Infrastructure in place to disconnect generation prior to parallel operation**
- **Commercial arrangements in place to support ‘connect and manage’**

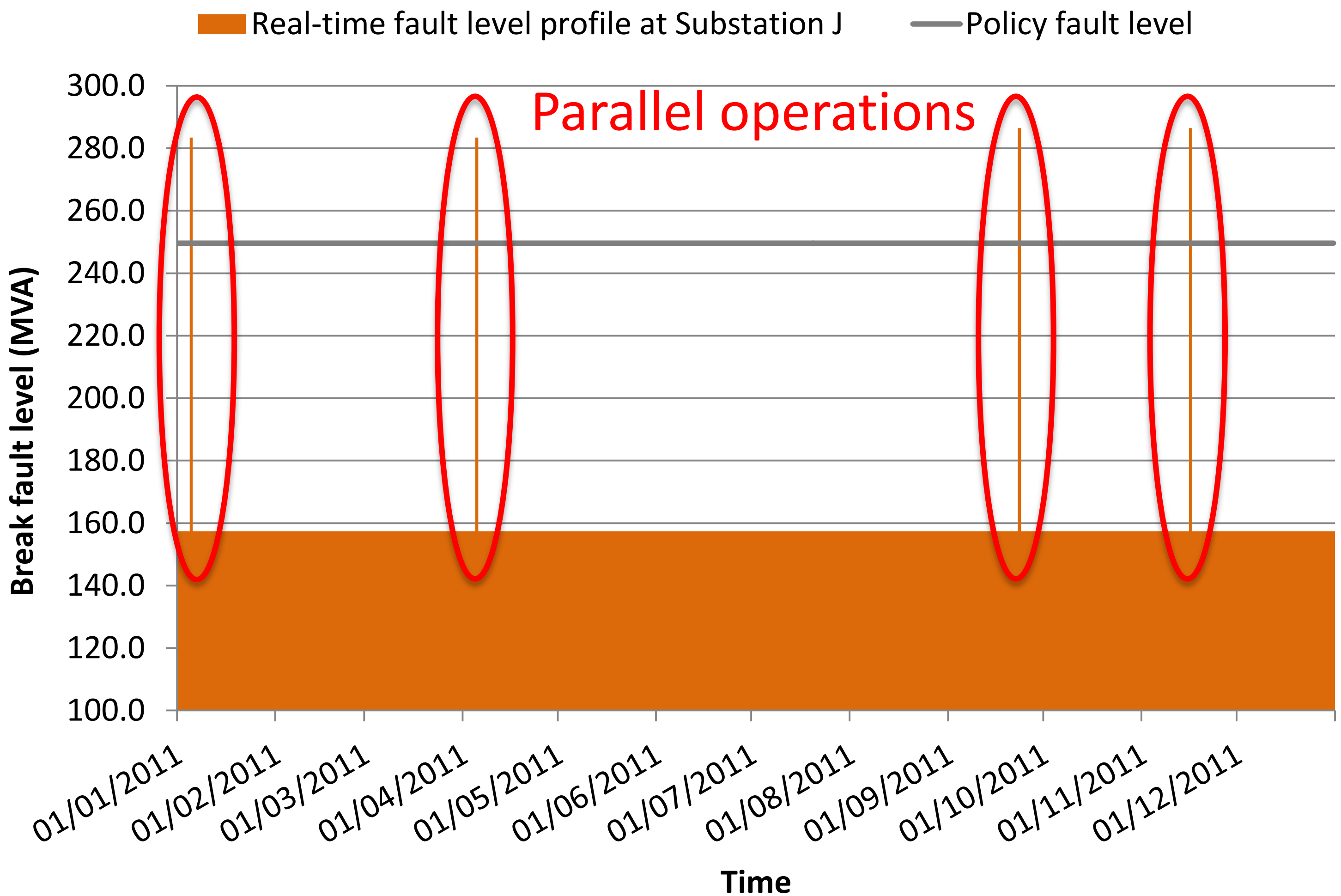
Operational configurations: Substation J



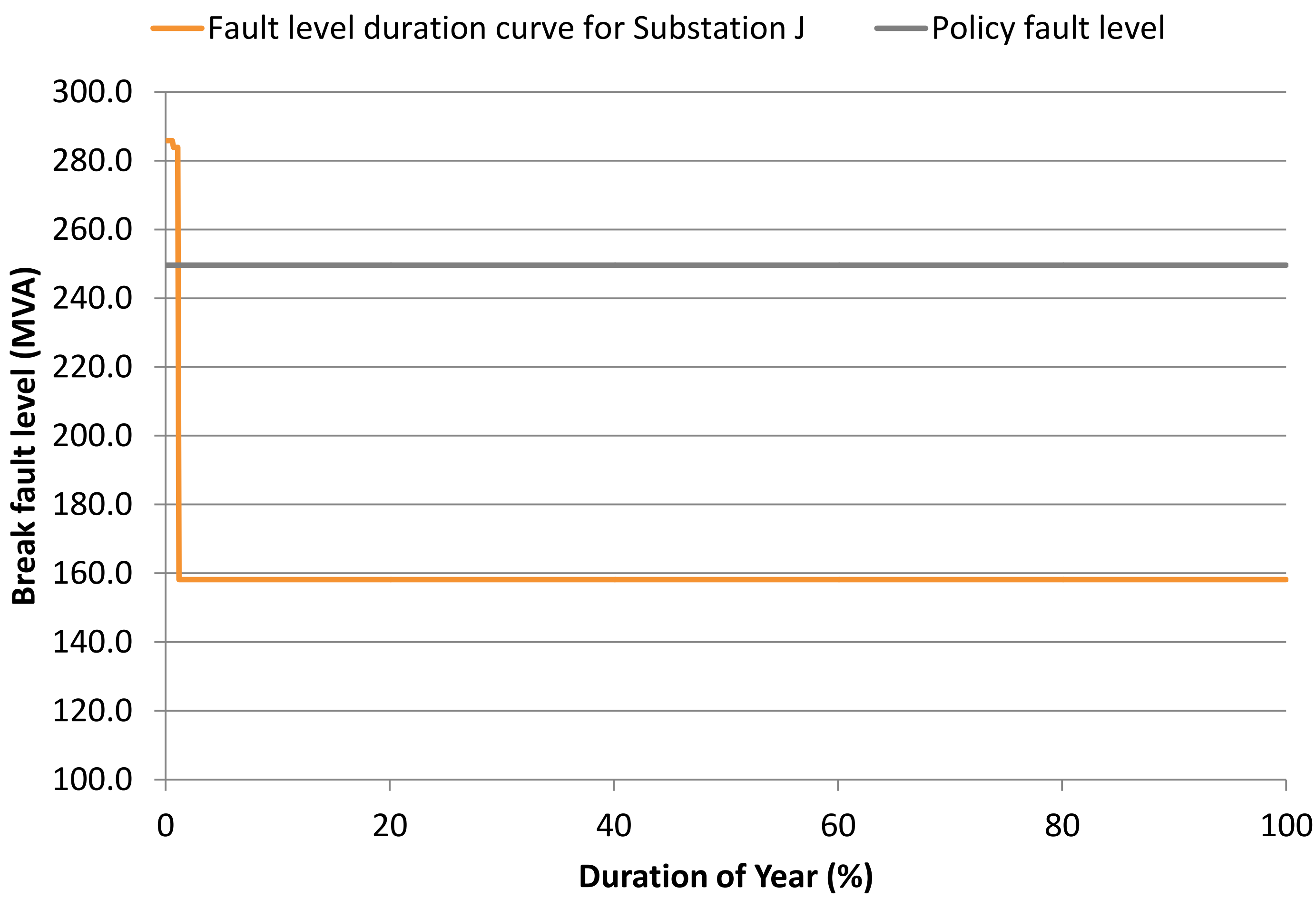
Time-series fault level profile



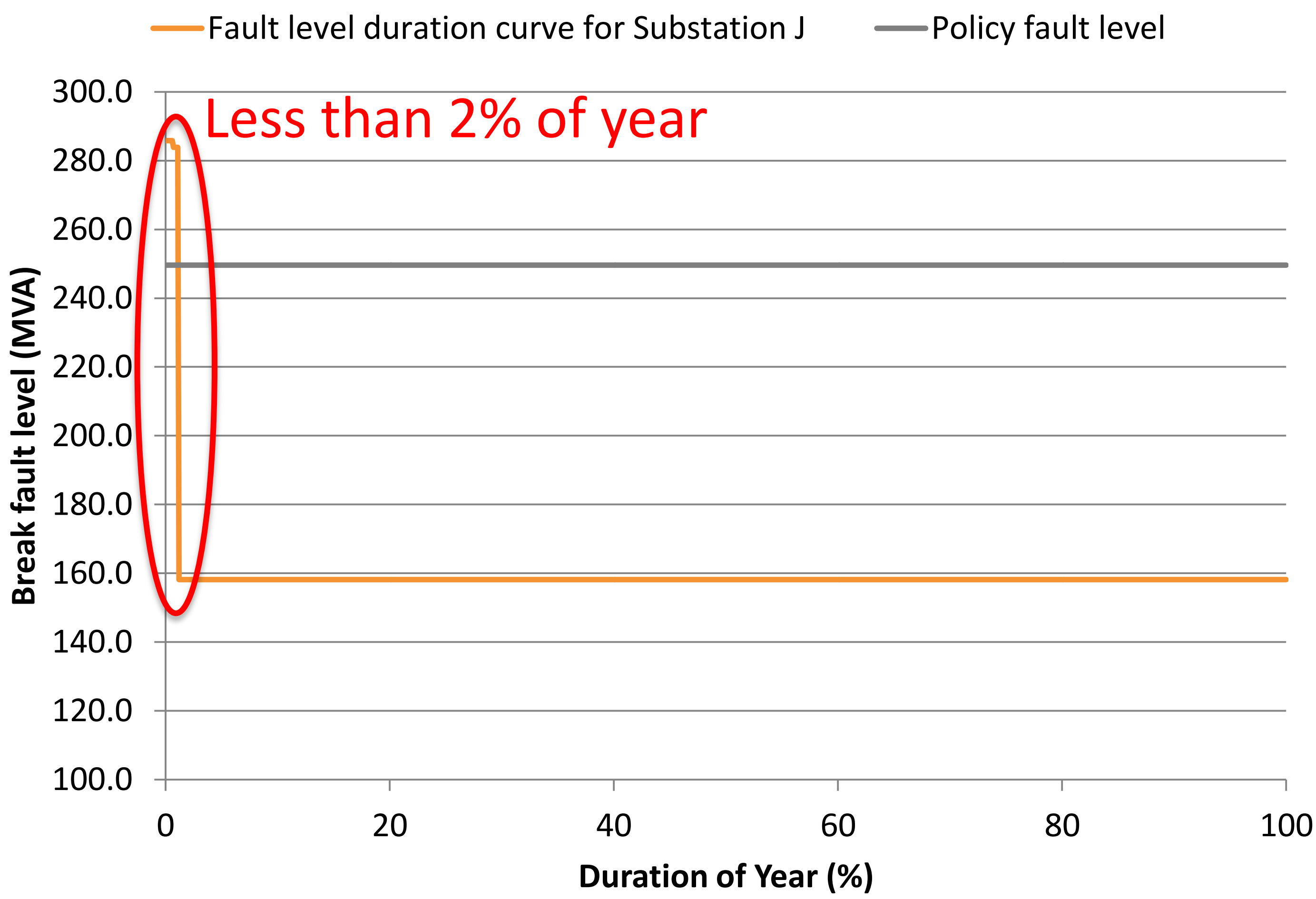
Time-series fault level profile



Fault level duration curve



Fault level duration curve



Generation headroom analysis methodology

Step 1
- Quantify the MVA headroom between 'split' network fault level and policy fault level value
- Convert to MW headroom using MVA / MW factor

Step 2
- Quantify unconstrained energy yield, constrained energy yield, net energy yield
- Perform cost-benefit analysis through £/MWh conversion

Step 3
- Technical basis of 'connect and manage' contract

Assumptions / caveats:

- **Safety margin on policy fault level value**
- **MVA / MW factor and generation capacity factor**
- **£/MWh and financial assumptions related to cost-benefit analysis**

Example results

Substation ID	Cumulative duration of parallels (%)	Parallel Fault Levels (kA) 3ph Break (rms)	Split Fault Levels (kA) 3ph Break (rms)	Switchgear rating (kA) 3ph Break (rms)	FL Headroom (kA)	FL Headroom (MVA)	Gen headroom (MW)
A	4.94%	15.7	8.5	13.1	4.6	87.6	19.5
B	0.05%	18.9	11.4	13.1	1.7	32.4	7.2
C	2.14%	14.6	7.8	13.1	5.3	101.0	22.4
D	0.09%	16.3	8.9	13.1	4.2	80.0	17.8
E	0.07%	16.1	8.7	13.1	4.4	83.8	18.6
F	0.03%	15.0	8.2	13.1	4.9	93.4	20.7
G	0.60%	14.2	11.6	13.1	1.5	28.6	6.4
H	0.12%	16.7	9.0	13.1	4.1	78.1	17.4
I	0.01%	15.9	8.4	13.1	4.7	89.5	19.9
J	2.01%	15.0	8.2	13.1	4.9	93.4	20.7

Analysis:

- **Each substation has a fault level issue when parallel operations take place**
- **Due to space availabilities, some substations are more suitable for fault current limiter technologies and some substations are more suitable for fault level management**

Evaluation

Pros:

- Avoids network reinforcement
- Readily integrate generation with limited network reconfiguration
- Potentially quicker and cheaper customer connections
- Can use present fault level values or ‘enhanced’ assessment values

Cons:

- Additional communications infrastructure to control generation connection, additional risk
- Limited impact on CI / CML improvement

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Presentation 2 – Topic Focus:

Method Gamma:

Fault level mitigation

Neil Murdoch

Senior Engineer, Parsons Brinckerhoff

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FlexDGrid – Method Gamma

Three integrated Methods leading to quicker and cost effective HV customer connections through a timely step change in the enhanced understanding, management and mitigation of distribution network fault level

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- Utilised from output of Management

Introduction

- Update on Method Gamma
- Specifying FCLs
- Considerations for FlexDGrid sites
- Summary

Method Gamma Update

- Method Gamma: Fault Level Mitigation Technologies
  - Build on knowledge learned through IFI, ETI and LCNF Projects
  - Install 5 FL mitigation technologies in 5 separate WPD substations
  - Test & trial emerging technologies to quantify performance and network benefits

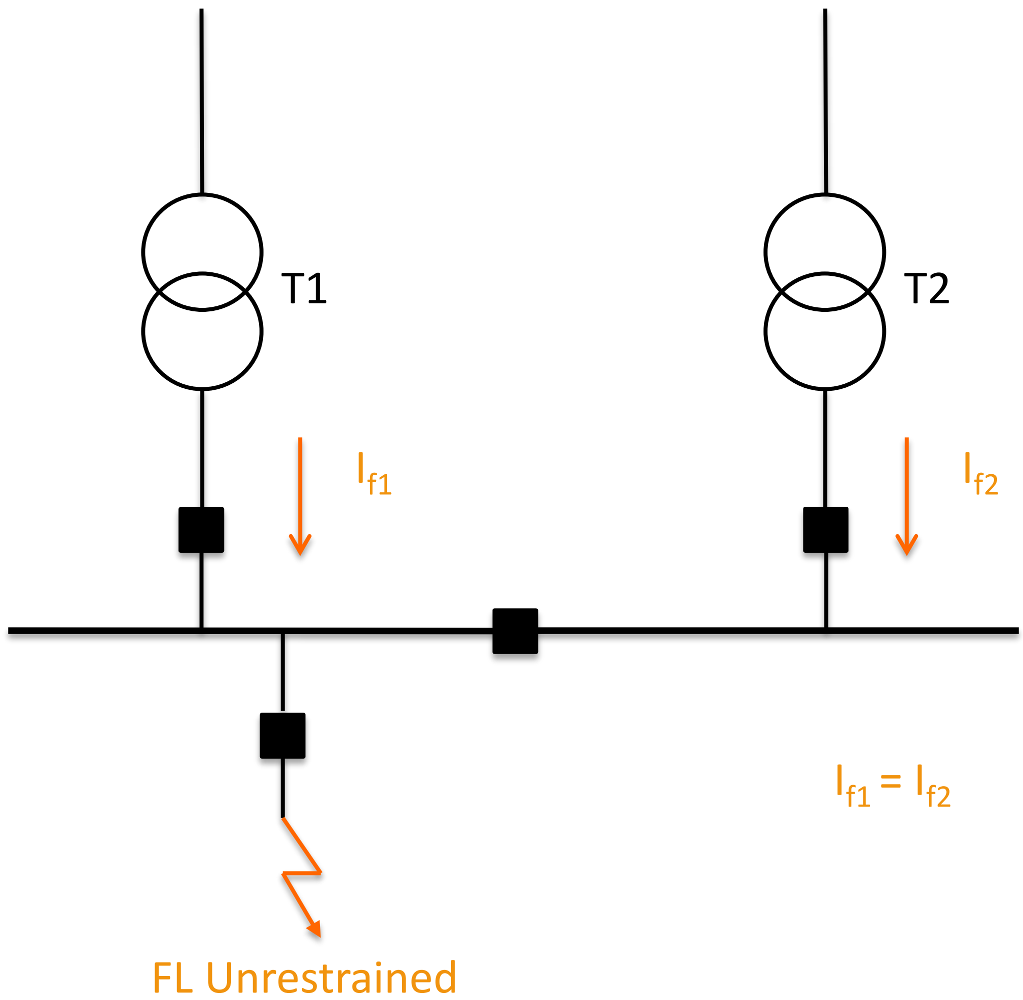
Method Gamma Update

- Specified requirements for FCLs at each substation
- ITT released in June 2013
- Post Tender Negotiations Complete
- SDRC-6 submitted to Ofgem for approval
- Contract awards December 2013 (provisional)
- Conceptual designs underway

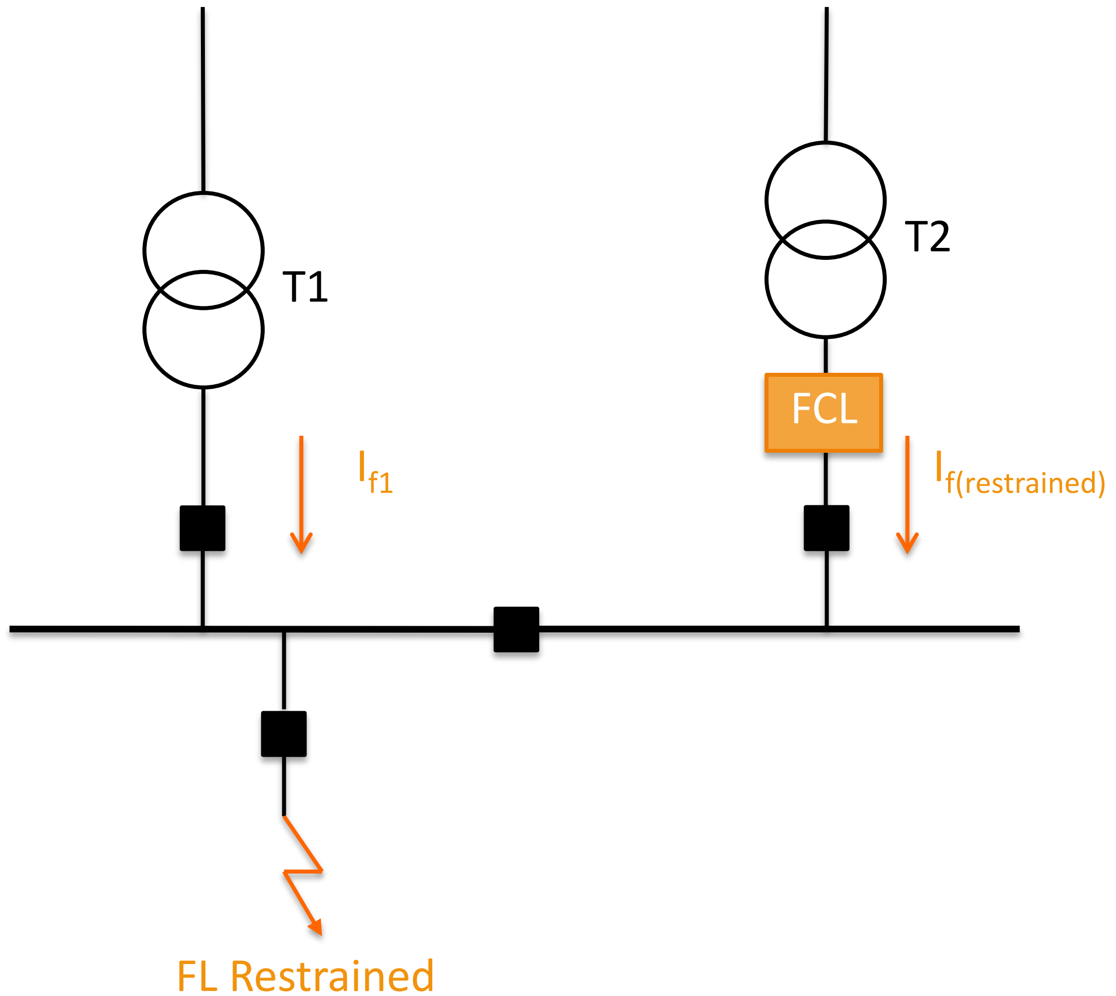
Specifying FCLs

- As part of the ITT a range of functional requirements were provided to the Tenderers:
  - **Voltage (normal and withstand)**
  - **Rating (continuous current)**
  - **Typical specifications (IEC, BS and ENA – where applicable)**
- In addition, it was critical to specify the prospective fault levels and level of reduction required
  - **This can be expressed in two ways: Overall and through the source**

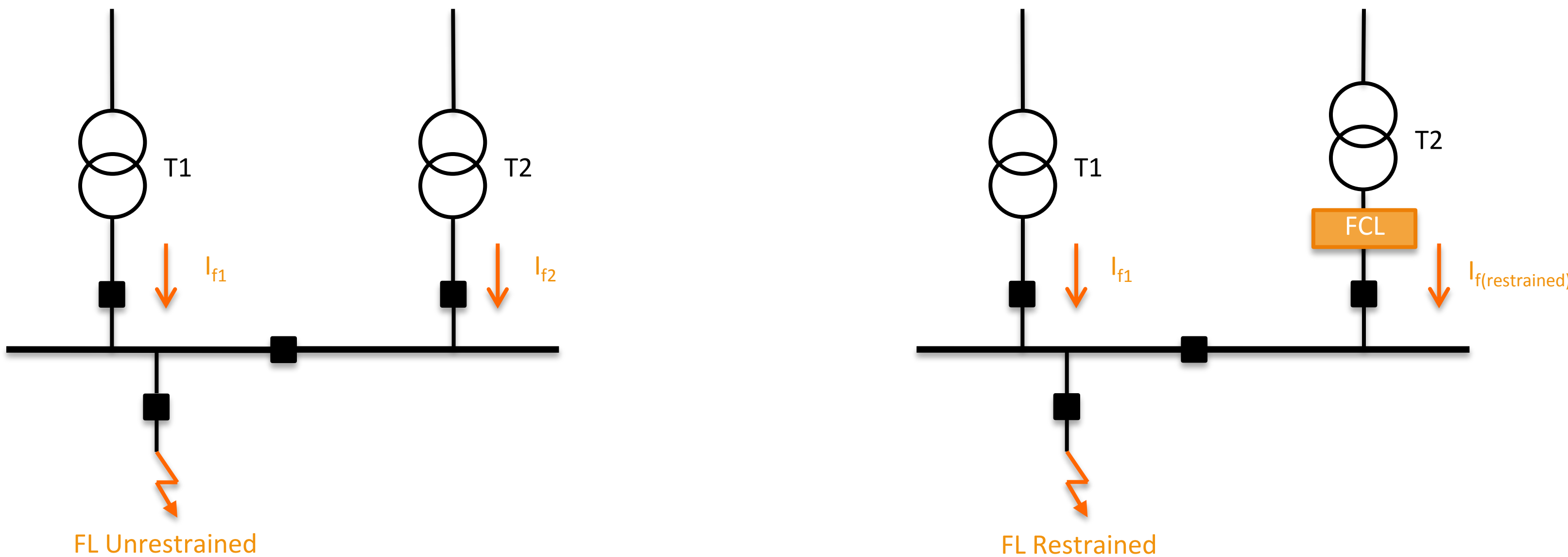
Example: Existing Parallel Fault Level



Example: With FCL added



Example: Calculation of reduction



FCL Requirements:

Overall Reduction = $(FL_{Unrestrained} - FL_{Restrained})/FL_{Unrestrained} \times 100 = XX\ \%$

T2 Reduction = $(I_{f2} - I_{f(restrained)})/I_{f2} \times 100 = YY\ \%$

Specifying FCLs

- Following information was requested from manufacturers to aid with the FCL evaluation:
  - General operation and maintenance requirements
  - Proposed dimensions and mass
  - Recovery / reset times
  - H&S implications (potential EMFs, non standard equipment)
  - Previous experience / installations
  - Costs, lead-times, T&Cs etc…

Specifying FCLs

- Proposals were evaluated individually per substation
  - **Does it meet the required FL reduction requirements?**
  - **Physical size of the proposed solution – can it be accommodated?**
  - **Are there any deviations from the functional specification?**

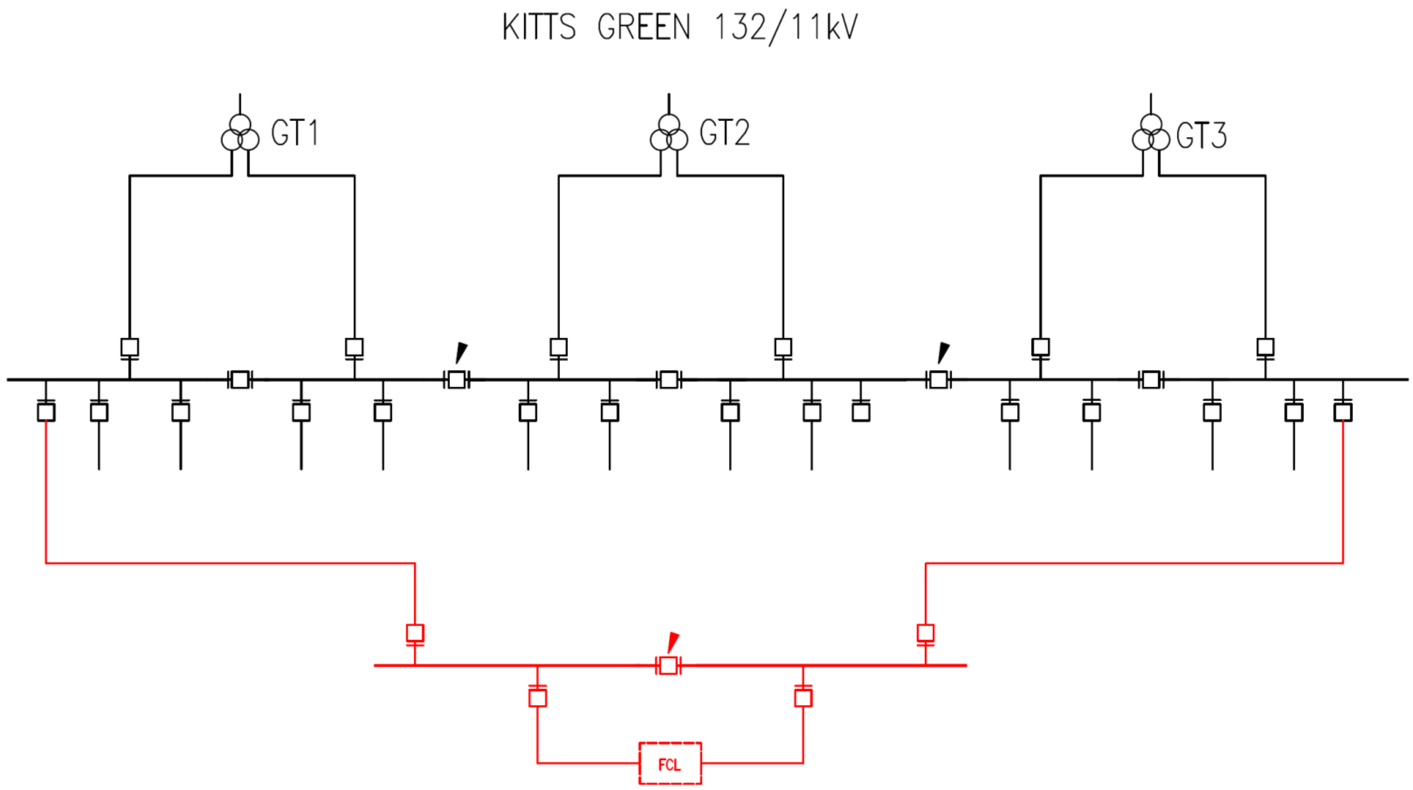
FCLs for FlexDGrid

- Kitts Green
- Castle Bromwich
- Chester Street
- Bournville
- Sparkbrook

Kitts Green 132/11kV

- 3 no. 132/11/11kV transformers
- When operating in parallel at 11kV, 3ph break FL is 15.7kA
- Target 3ph break FL is 9.4kA with FCL
- FCL to be connected into 11kV interconnector

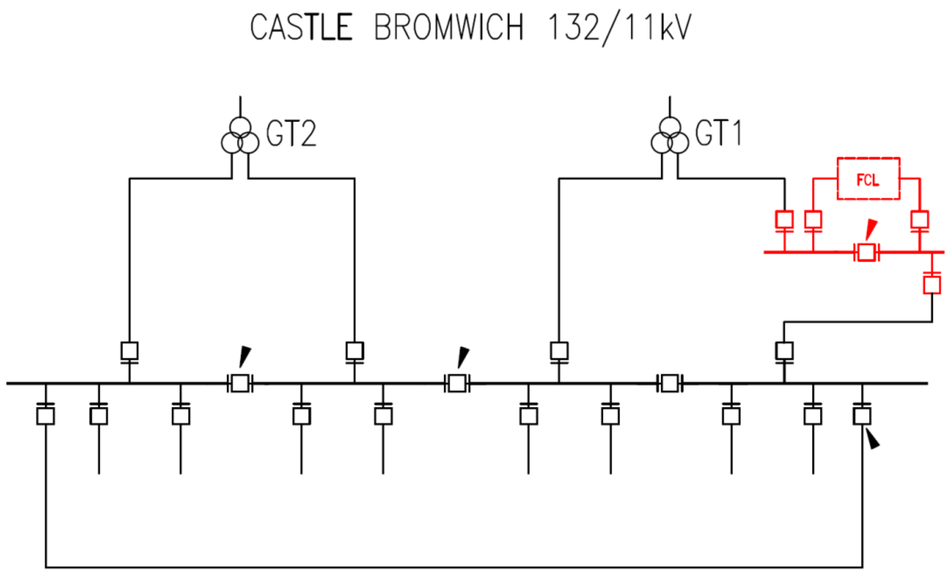
Kitts Green 132/11kV



Castle Bromwich 132/11kV

- 2 no. 132/11/11kV transformers supplied from separate Grid Supply Points
- When operating in parallel at 11kV, 3ph break FL is 13.7kA
- Target 3ph break FL is 11.3kA with FCL
- FCL to be connected into 11kV transformer ‘tails’

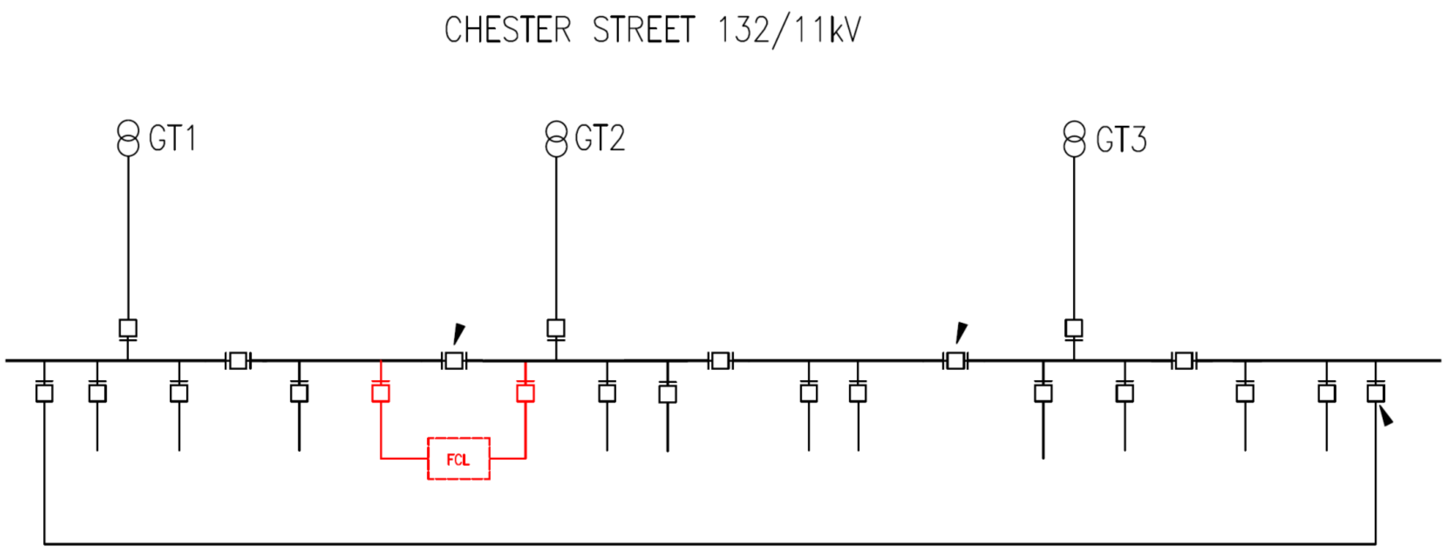
Castle Bromwich 132/11kV



Chester Street 132/11kV

- 3 no. 132/11kV transformers, one supplied from separate Grid Supply Point
- 11kV switchgear is being replaced under DPCR5
- When operating in parallel at 11kV, 3ph break FL is 14.1kA
- Target 3ph break FL is 11.3kA with FCL
- FCL to be connected across bus-section

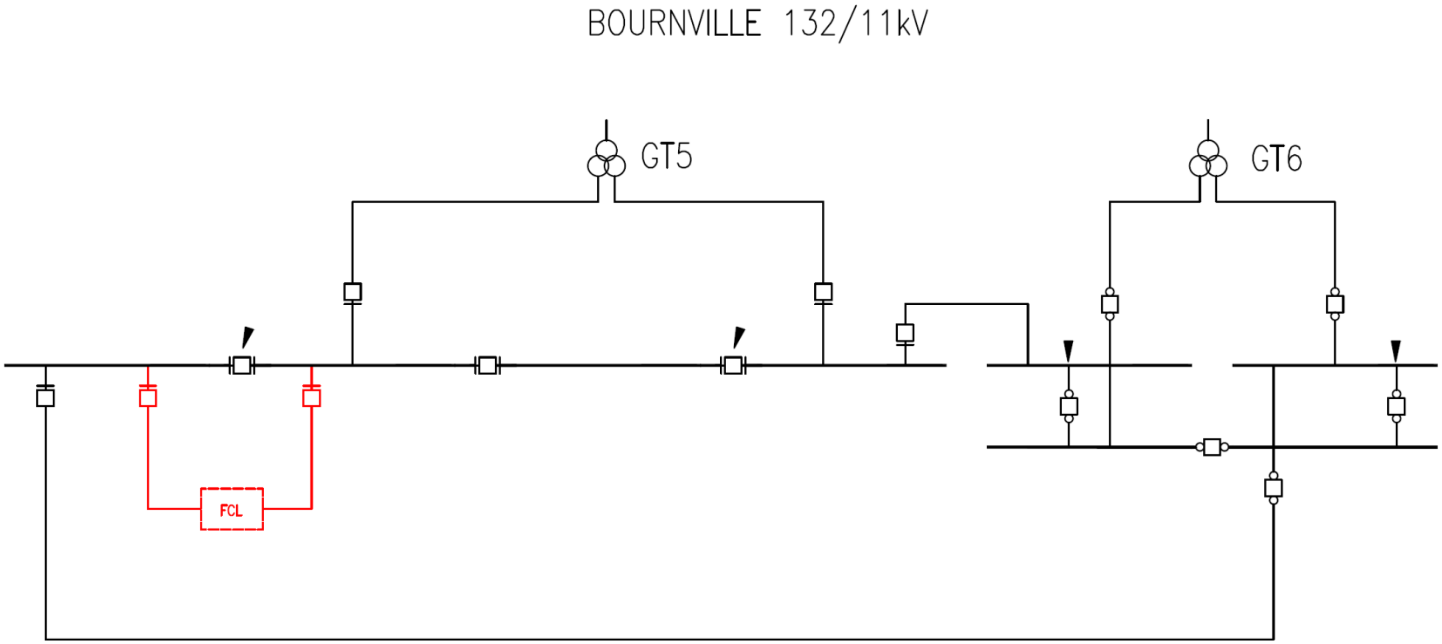
Chester Street 132/11kV



Bournville 132/11kV

- 4 no. 132/11kV transformers
- Transformers and 11kV switchgear are scheduled for replacement
- When operating in parallel at 11kV, 3ph break FL is 15.3kA
- Target 3ph break FL is 11.3kA with FCL
- FCL to be connected across bus-section

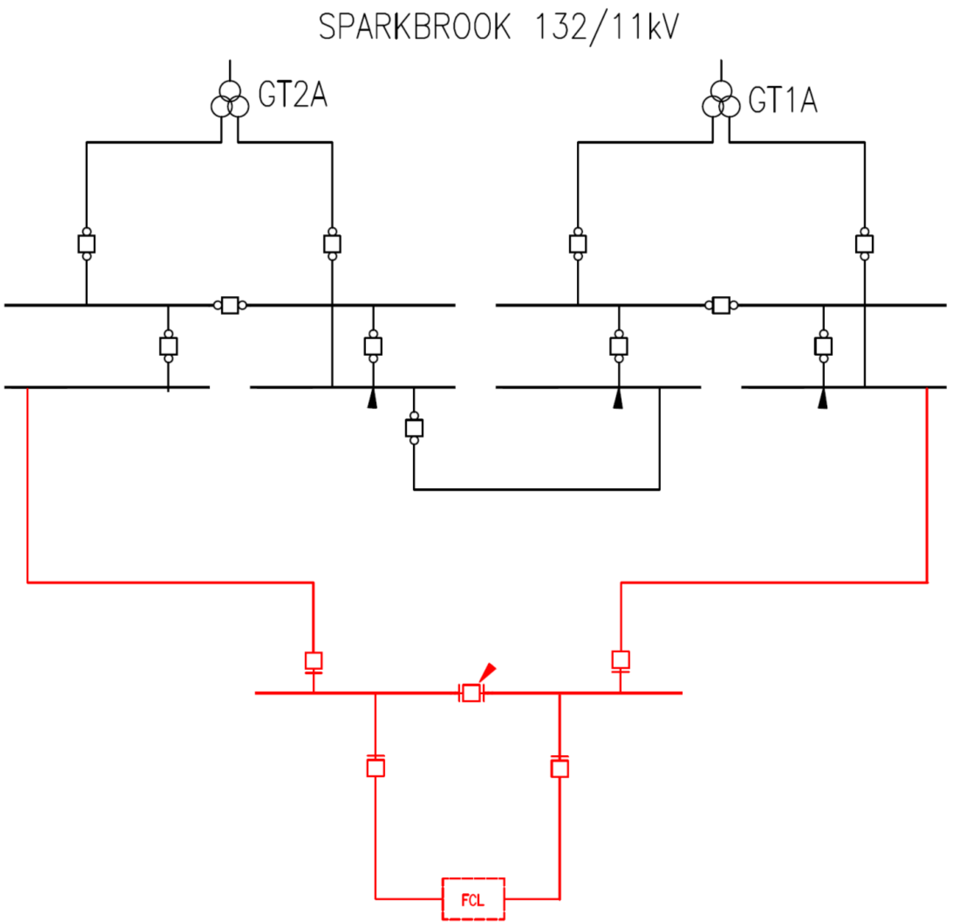
Bournville 132/11kV



Sparkbrook 132/11kV

- 2 no. 132/11/11kV transformers
- When operating in parallel at 11kV, 3ph break FL is 16.1kA
- Target 3ph break FL is 11.3kA with FCL
- FCL to be connected into 11kV interconnector

Sparkbrook 132/11kV



Summary

- Any technologies that could not meet the fundamental requirements were rejected
- Remaining technologies were scored in line with the method explained in the ITT
- As the aim of FlexDGrid is to install and trial emerging technologies, a maximum of two of the same type of FCLs were considered across the five sites
- Contract awards December 2013 (provisional)

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Questions and Answers

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Lunch and Networking

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Agenda

10:00 – 10:30	**Arrival – Refreshments and Networking**
10:30 – 10:50	Round table introductions to include delegates' background in fault level modelling
10:50 – 11:00	Overview of FlexDGrid and the purpose of the workshop
11:00 – 11:30	Presentation 1 – Topic Focus: Dissemination of SDRC-1 (Enhanced fault level assessment processes)
11:30 – 12:05	Presentation 2 – Topic Focus: Monitoring and mitigation of fault level
12:05 – 12:30	Q&A session
12:30 – 13:15	Lunch and Networking
13:15 – 14:10	Discussion session 1: Monitoring of fault level and impact on connection applications
14:10 – 14:20	Break
14:20 – 15:15	Discussion session 2: Modelling of fault current limiters and impact on connection applications
15:15 – 15:30	Summary of workshop results and next steps
15:30	Close

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Discussion Session 1:

Monitoring of fault level and impact on connection applications

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Monitoring of fault level and impact on connection applications

1. What needs to be in place for fault level monitoring systems to be adopted?
   - From the DNO perspective / from the customer perspective

2. How would the network model and connection application process be modified if DNOs were able to access monitored fault level data?

3. What updates to G74 and Policy documents are needed and how should these documents be modified?

4. Any other discussions related to monitoring of fault level

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Discussion Session 2:

Modelling of fault current limiters and impact on connection applications

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Modelling of fault current limiters and impact on connection applications

1. What parameters should be modelled and what studies carried out to understand the behaviour of fault current limiters?

2. How should power system analysis packages be modified to accommodate fault current limiter models? (Define user requirements)

3. How should the connection application process and connection offers be modified to incorporate FCLs?
   a) Who should pay for what?
   b) How should connection charges be quantified?

4. Any other discussions related to modelling of fault current limiters

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Summary

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Thank you for joining us

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and have a safe journey home

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