WESTERN POWER DISTRIBUTION

FLEXDGRID

HEAT AND POWER FOR BIRMINGHAM

Fault Level Mitigation Technologies DNO Workshop

Wednesday 4th September 2013

LCN Fund Low Carbon Networks

THE UNIVERSITY OF WARWICK

PARSONS BRINCKERHOFF

Agenda

10:00 – 10:30	**Arrival – Refreshments and Networking**
10:30 – 11:10	Round table introductions to include delegates background in FCL work
11:10 – 11:30	Overview of FlexDGrid and the purpose of the workshop
11:30 – 12:00	Presentation 1 – Topic Focus: Modelling and Enhanced Fault Level Assessment
12:00 – 12:45	Presentation 2 – Topic Focus: Mitigation Technologies and approach to connection
12:45 – 13:30	Lunch and Networking
13:30 – 14:30	Discussion on FCL installation and implementation
14:30 – 14:45	Break
14:45 – 15:15	Sharing best practice options
15:15 – 15:30	Summary of workshop results and next steps
15:30	**Close**

Welcome and Introductions

DNO	Name	Job Title
WPD	Jonathan Berry	Innovation Engineer
WPD (Power Academy)	Aimée Slater	Student Engineer
WPD (Parsons Brinckerhoff)	Samuel Jupe	FlexDGrid EFLA Lead
WPD (Parsons Brinckerhoff)	Neil Murdoch	FlexDGrid Distribution Lead
UKPN	Ian Cooper	Senior Technology Transfer Engineer
UKPN	Allan Boardman	Network Design Standards Manager
UKPN	David Boyer	Solution Design Authority - Low Carbon London
SSE	Tawanda Chitifa	R&D Project Manager
SPEN	Eric Leavy	Head of Design
ENWL	Geraldine Bryson	Future Networks Technical Manager
NPG	Dr. Roshan Bhattarai	System Planning Engineer

Overview of FlexDGrid and workshop aims

Jonathan Berry
Western Power Distribution

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Methods Alpha and Beta

Enhanced fault level assessment and modelling

Samuel Jupe MEng PhD CEng MIET

Senior Engineer, Parsons Brinckerhoff

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Agenda

- Overview of Methods
- Method Alpha
  - Processes
  - Emerging learning
  - Next steps
- Method Beta
  - Trials
  - System design
  - Next steps
- Integrated Methods

Overview of Methods

- There are three separate Methods identified in FlexDGrid:
  - **Method Alpha: Enhanced Fault Level Assessment**
    - **Focus on modelling fault levels at 15 Primary Substations and 11kV network**
    - **Provide datum metrics by which benefits of practical trials can be assessed**
  - **Method Beta: Real-time Management of Fault Level**
    - **Focus on measurement and monitoring of 11kV fault level at 10 Primary Substations**
  - Method Gamma: Fault Level Mitigation Technologies

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

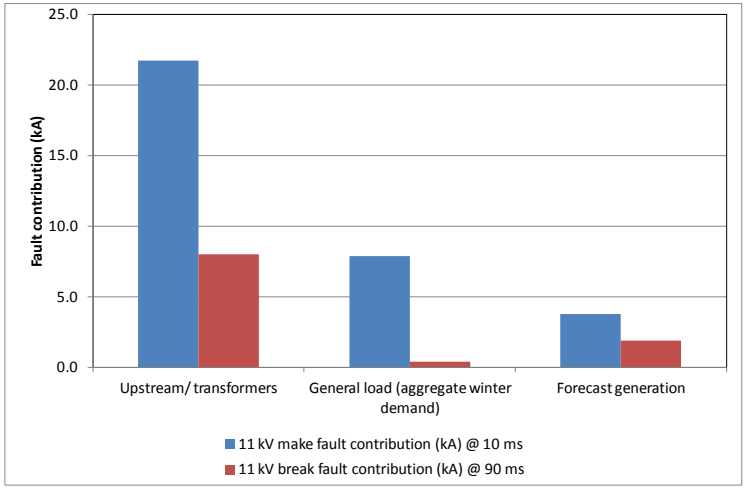
5. For training and consistency, DNOs should formally document their connection study process

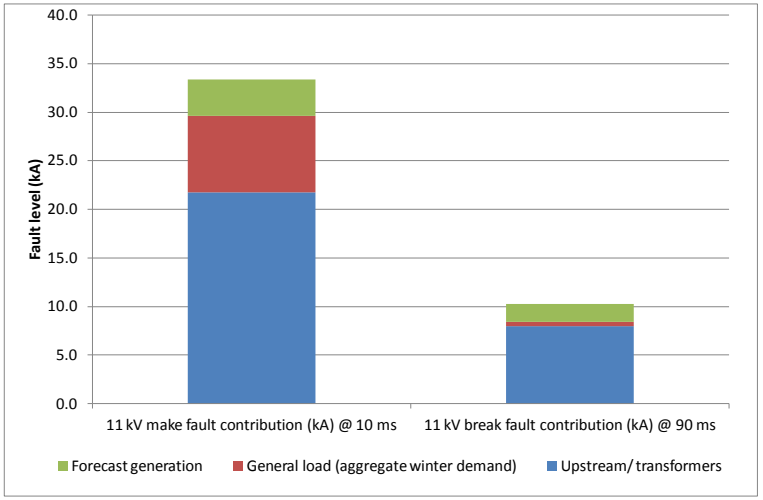
6. Development of integrated EHV and HV electricity network models

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

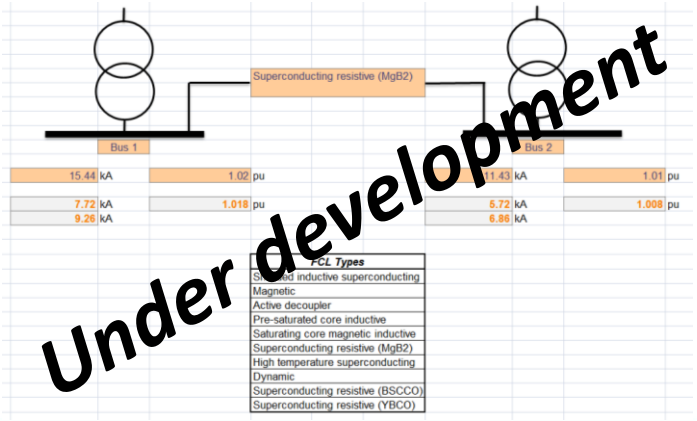
Method Alpha: Next Steps

- Fault level decomposition





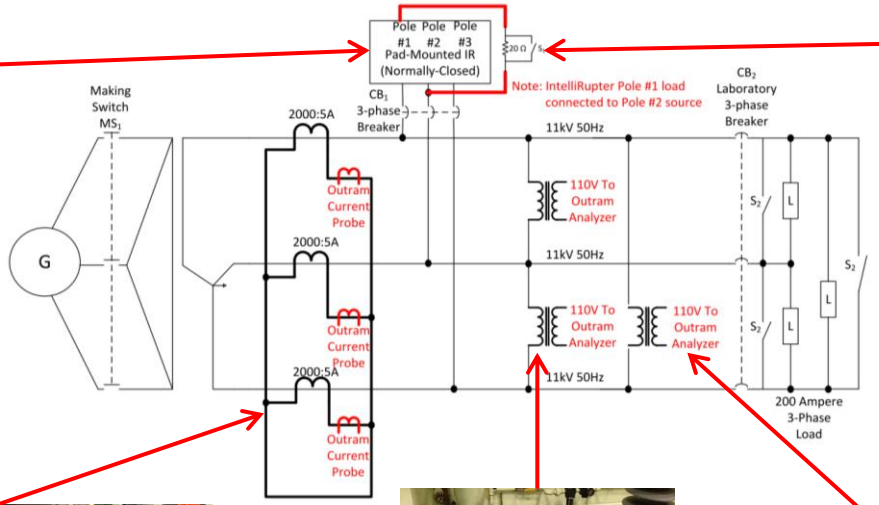
- Fault current limiter models
  - Functional specification
  - Excel interface
  - PSS/E ‘black box’



Method Beta: Real-time fault level management

IntelliRupter

Example monitoring system



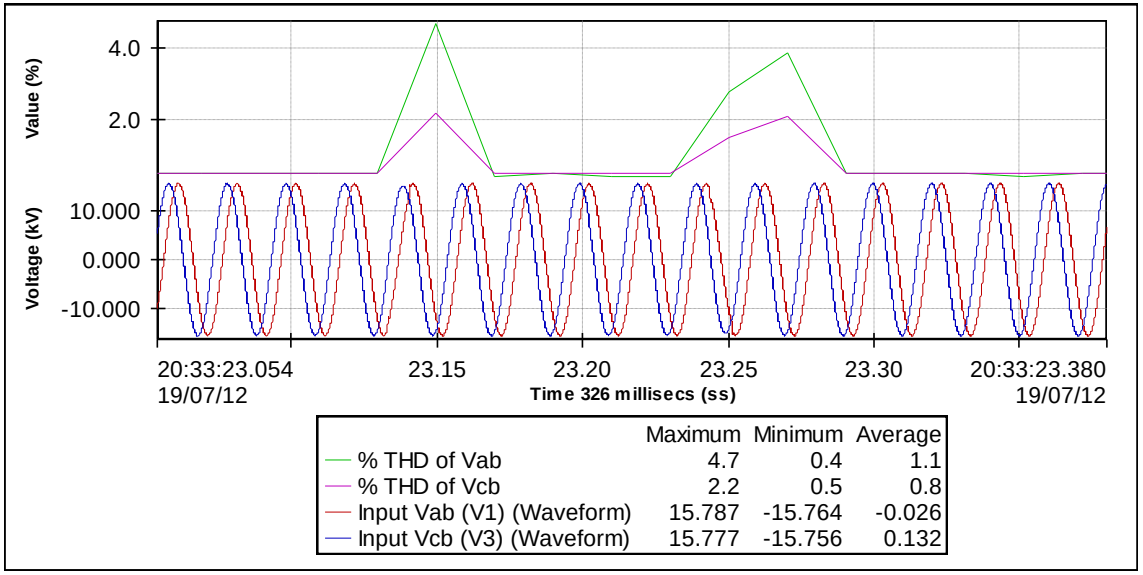
Inductor

Current Transformers

Voltage Transformers

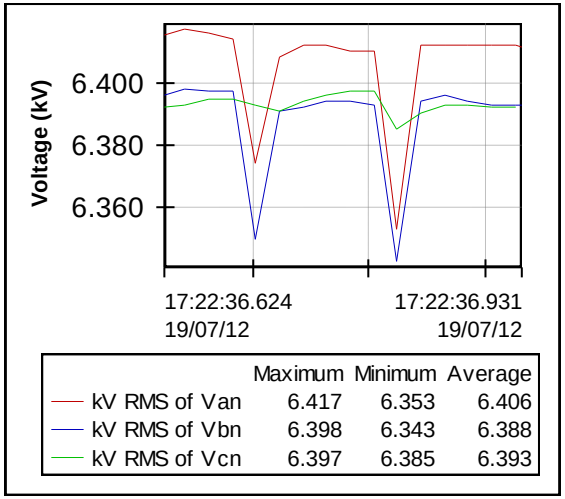
PM7000 - FLM

Method Beta: Results



	Maximum	Minimum	Average
% THD of Vab	4.7	0.4	1.1
% THD of Vcb	2.2	0.5	0.8
Input Vab (V1) (Waveform)	15.787	-15.764	-0.026
Input Vcb (V3) (Waveform)	15.777	-15.756	0.132

Harmonic distortion caused by FLM



	Maximum	Minimum	Average
kV RMS of Van	6.417	6.353	6.406
kV RMS of Vbn	6.398	6.343	6.388
kV RMS of Vcn	6.397	6.385	6.393

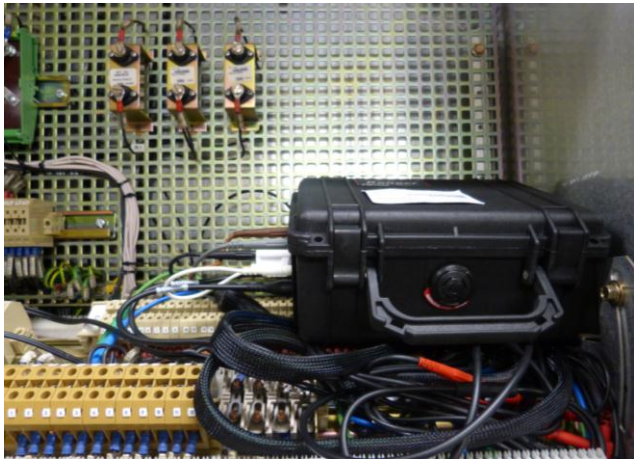
Voltage fluctuation caused by FLM

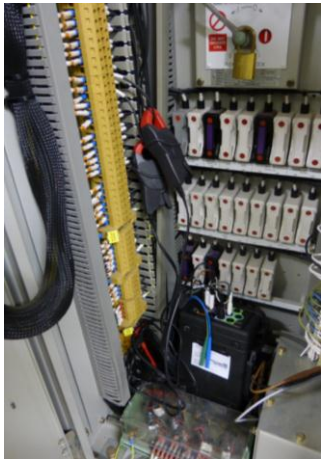
- Both tests were carried out using the factory acceptance test arrangement
- Maximum voltage fluctuation is 1% in a 300ms timeframe (ER P28 compliant)
- Maximum Total Harmonic Distortion is 4.7% in a 300ms timeframe (ER G5/4 compliant)
- **Fault Level prediction accuracy within 4.5%**

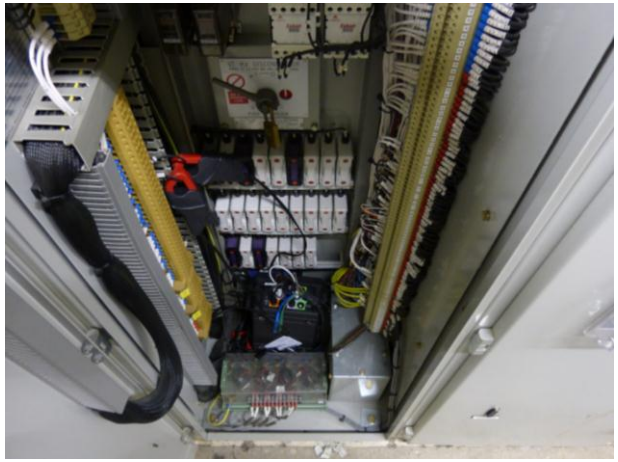
Method Beta: Next Steps

- Currently out to tender for fault level monitoring devices

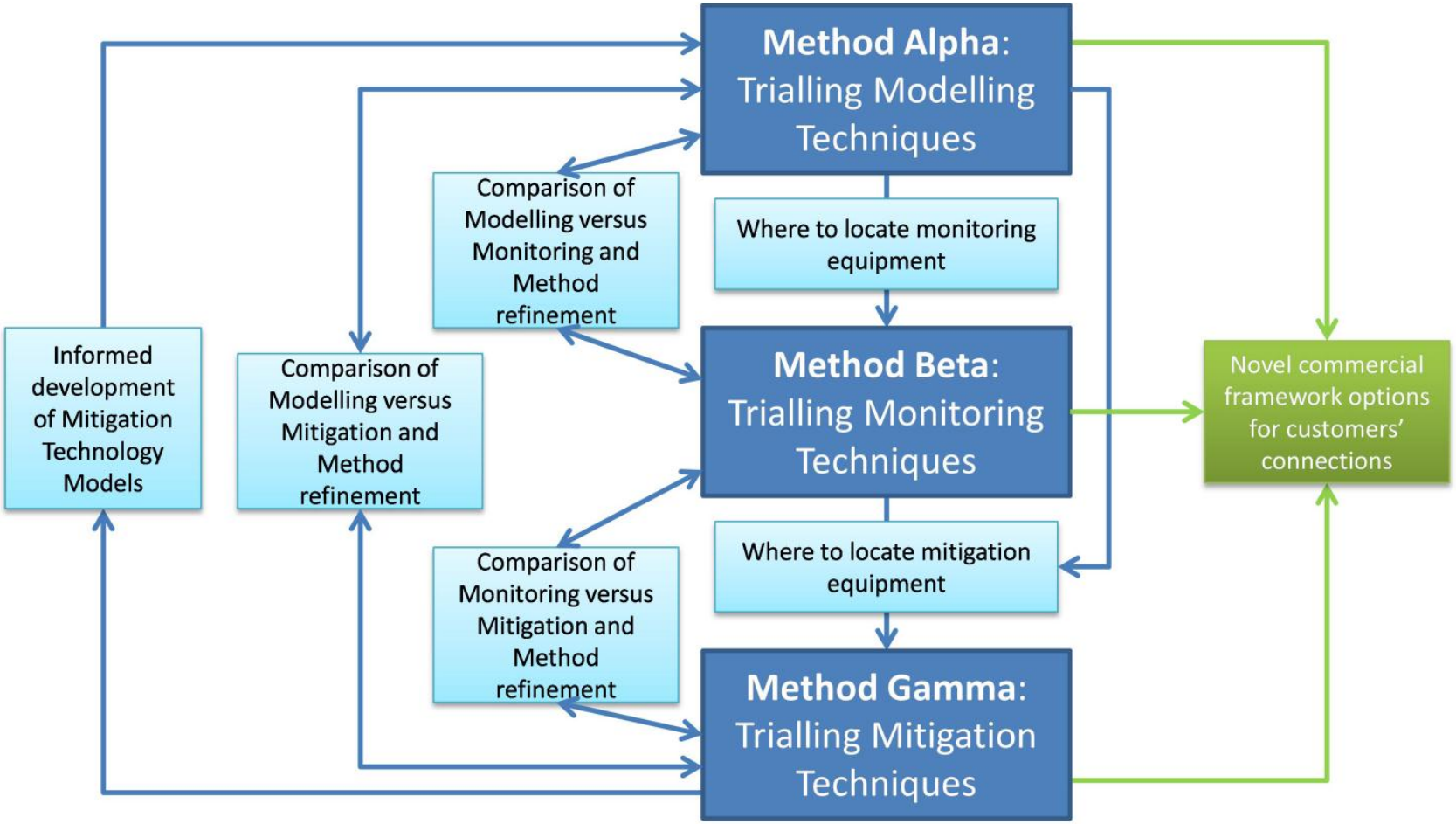
- PM7000 measurement devices have been installed at 3 out of 10 Primary Substations to date







Integrated Methods and Expected Learning



Any Questions?

Date for the diary:
DNO Workshop on the Implementation of
Enhanced Fault Level Assessment Processes
Wednesday 23 October 2013
Austin Court, IET Birmingham

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Method Gamma

Proposed Methodology for Method Gamma

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Agenda

- Method Gamma Objectives
- Fault Level Mitigation Methods
- Overview of Emerging Fault Current Limiter Technologies
- Substation Selection Process
- Connection Options for Technologies
- Technology Integration for FlexDGrid Substations

Method Gamma Objective

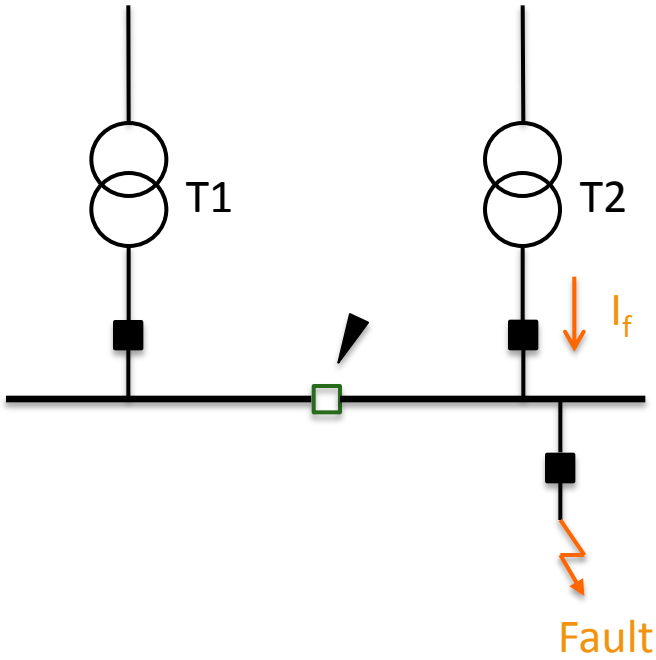
- There are three separate methods identified for FlexDGrid:
  - Method Alpha: Enhanced Fault Level Assessment
  - Method Beta: Real-time Management of Fault Level
  - **Method Gamma: Fault Level Mitigation Technologies**
    - **Build on knowledge learned through IFI, ETI and LCNF Projects**
    - **Install 5 FL Mitigation Technologies in 5 separate WPD substations**
    - **Test & Trial Technologies to quantify performance and network benefit**

Fault Level Mitigation Methods

- There are number of established and emerging methods to manage Fault Level on Power Networks.
  - Network Operation, running “split” or “open”
  - Bus-section reactor
  - **Pre-Saturated Core FCL**
  - **Resistive Superconducting FCL**
  - **Power Electronic FCL**

Network Running "Open"

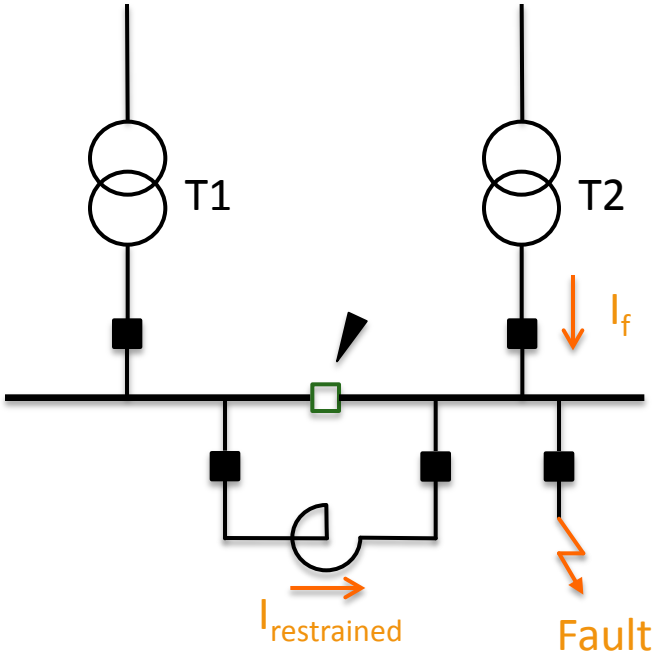
– Run the network "open" or "split" to avoid parallels between two sources



- ✓ Simple to implement
- ✓ Large reduction in FL
- ✓ Zero cost
- ✗ Large reduction in security
- ✗ Can reduce firm capacity
- ✗ Loads on busbars need to be balanced (tx sharing)

Bus-Section Reactor

– Install a reactor between two busbars to create a “loose couple” arrangement



- ✓ Proven technology
- ✓ Security of supply
- ✓ Installation/Maintenance similar to transformer
- ✗ Losses
- ✗ Limited fault level reduction
- ✗ Can limit load flow as well as fault level

Emerging FCL Technologies Considered

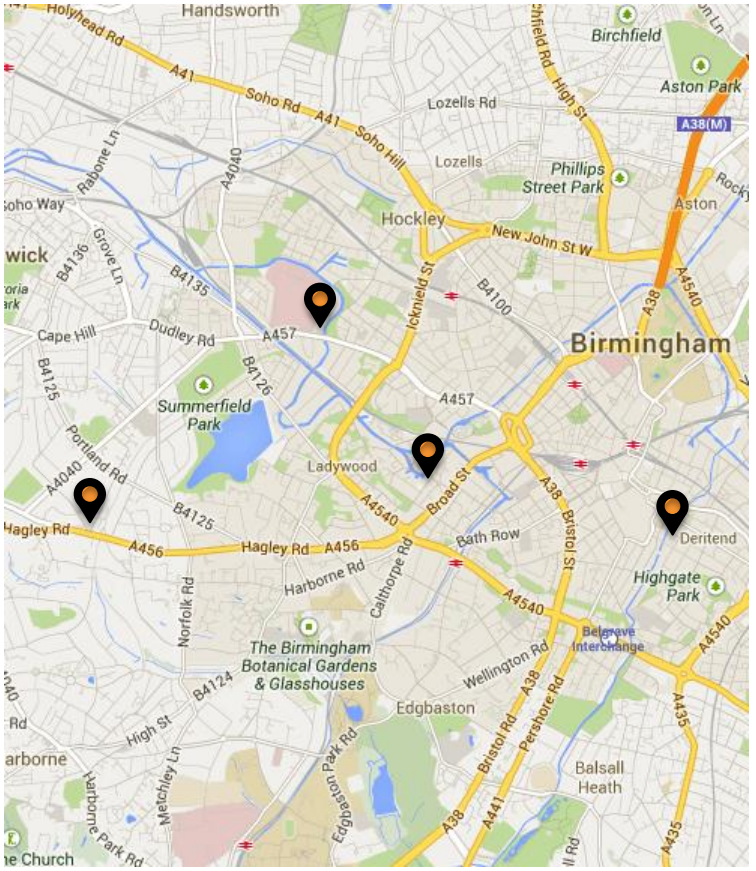
- **Pre-Saturated Core FCL**
  - Design similar to a transformer, the iron core is normally saturated by a DC coil secondary winding (can be superconducting)
- **Resistive Superconducting FCL**
  - High Temperature Superconductor inserted in series with the network. Can be used in conjunction with a shunt reactor / resistor
- **Power Electronic FCL**
  - Uses self-commutated semiconductor devices to interrupt fault current

Emerging FCL Technologies Considered

- Open, competitive tender process currently ongoing for FlexDGrid
- New technologies must be fail-safe to allow connection to the network
- Advantages of new technologies include
  - High percentage FL reduction
  - 'Invisible' during normal operation
  - Low losses

Substation Selection

- 18 substations identified in and around Birmingham with FL issue
- 5 sites for FCL selected:
  - Availability of Space
  - Network Connection
  - Substation Access
  - Investment Plans
  - Auxiliary Equipment



Availability of Space

- Purchase of land can be expensive and time consuming
- Use of spare land considered in proximity to the connection point
- Checks with Primary System Engineers to ensure land is not required for future developments

Network Connection

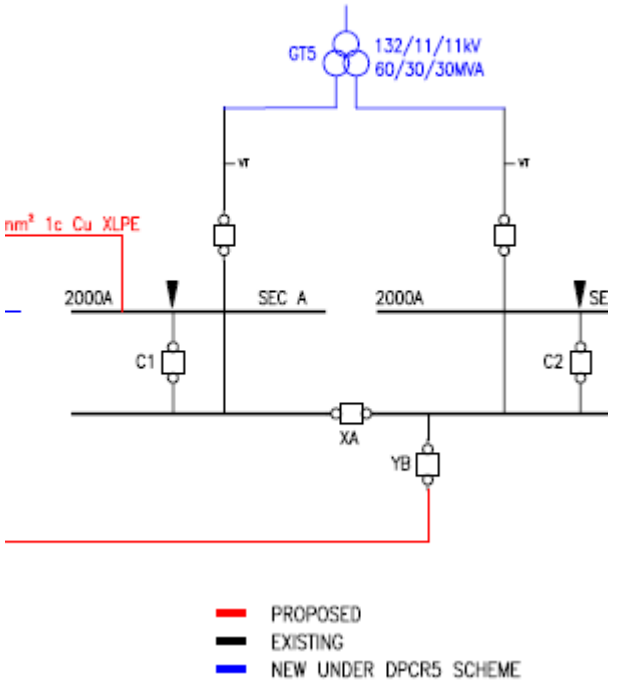
- Consider the complexity of connection to the 11kV network
- Where possible avoid extensive alterations to protection schemes
- Connection options are considered later in the presentation

Substation Access

- FCLs can be large in size
- Ensure delivery and off-loading of equipment in built areas is feasible without major alterations to the substation
- Be aware of clearances and access for future replacement of transformers etc.

Investment Plans

- Careful consideration for substations that are earmarked for load and non-load related reinforcement
- Avoid locating equipment where it may hinder future expansion/replacement
- Savings by incorporating FCL switchgear in plans



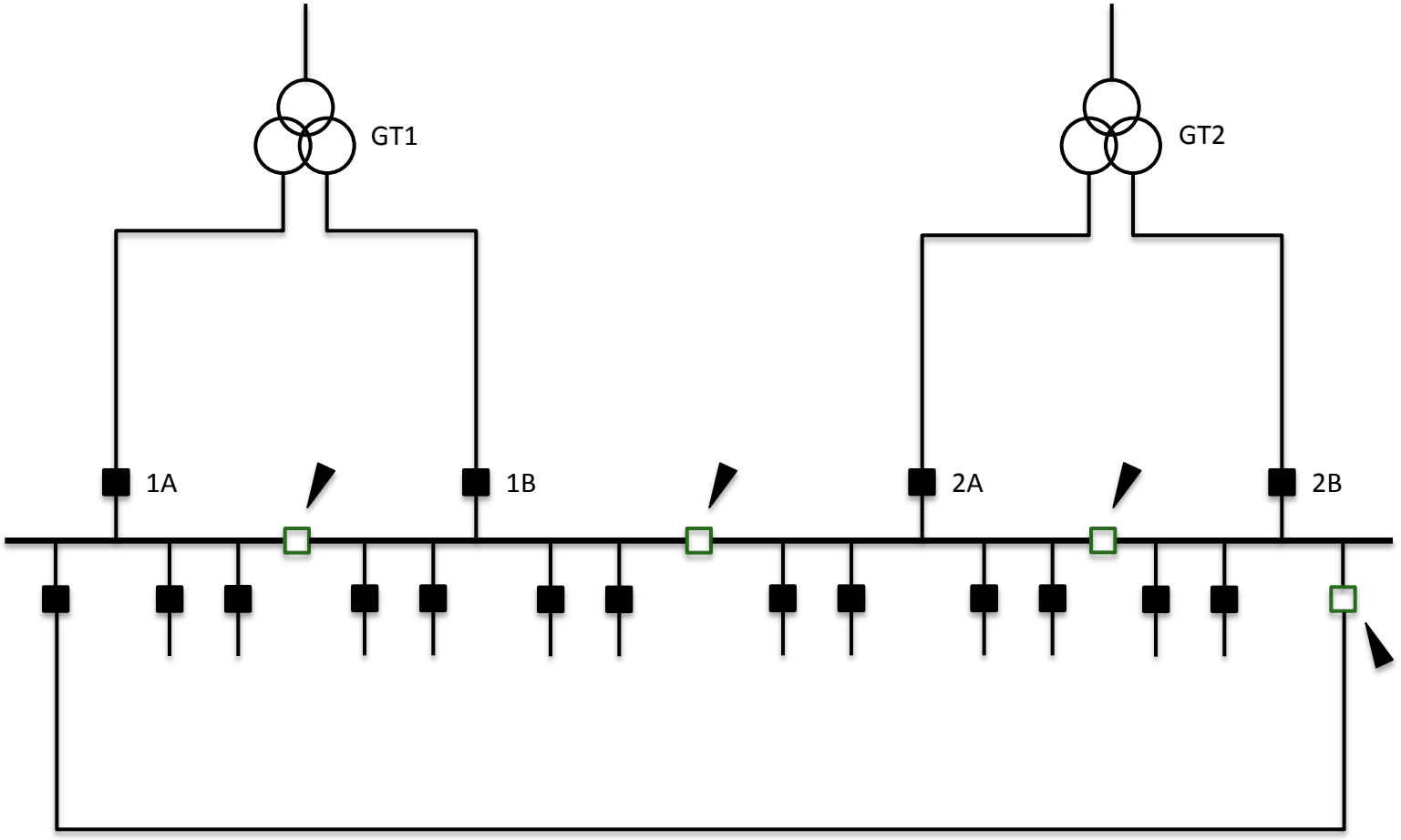
Auxiliaries

- Check the availability/capacity of existing systems (LVAC, 110V, 48V and SCADA)
- New FCL equipment (and switchgear) may require extensions and/or replacement of these systems

Birmingham Distribution Network

- The network in Birmingham has evolved over time and there is limited 33kV network in the area
- All of the sites shortlisted for FlexDGrid were 132/11kV substations with higher 11kV fault levels than would be seen at a normal 33/11kV substation
- The majority of substations have dual wound, 132/11kV, 60/30/30MVA transformers

Typical substation configuration



Operating Arrangement

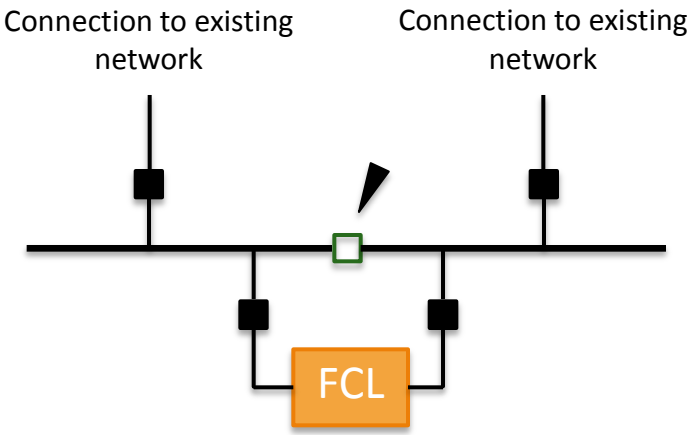
- To minimise the impact of fault level on the network, bus-sections are run open
- 11kV primary and secondary switchgear have a ‘break’ rating of 250MVA
- Auto-switching schemes are in place to restore customers following interruptions to the incoming supply

FCL Connection Options

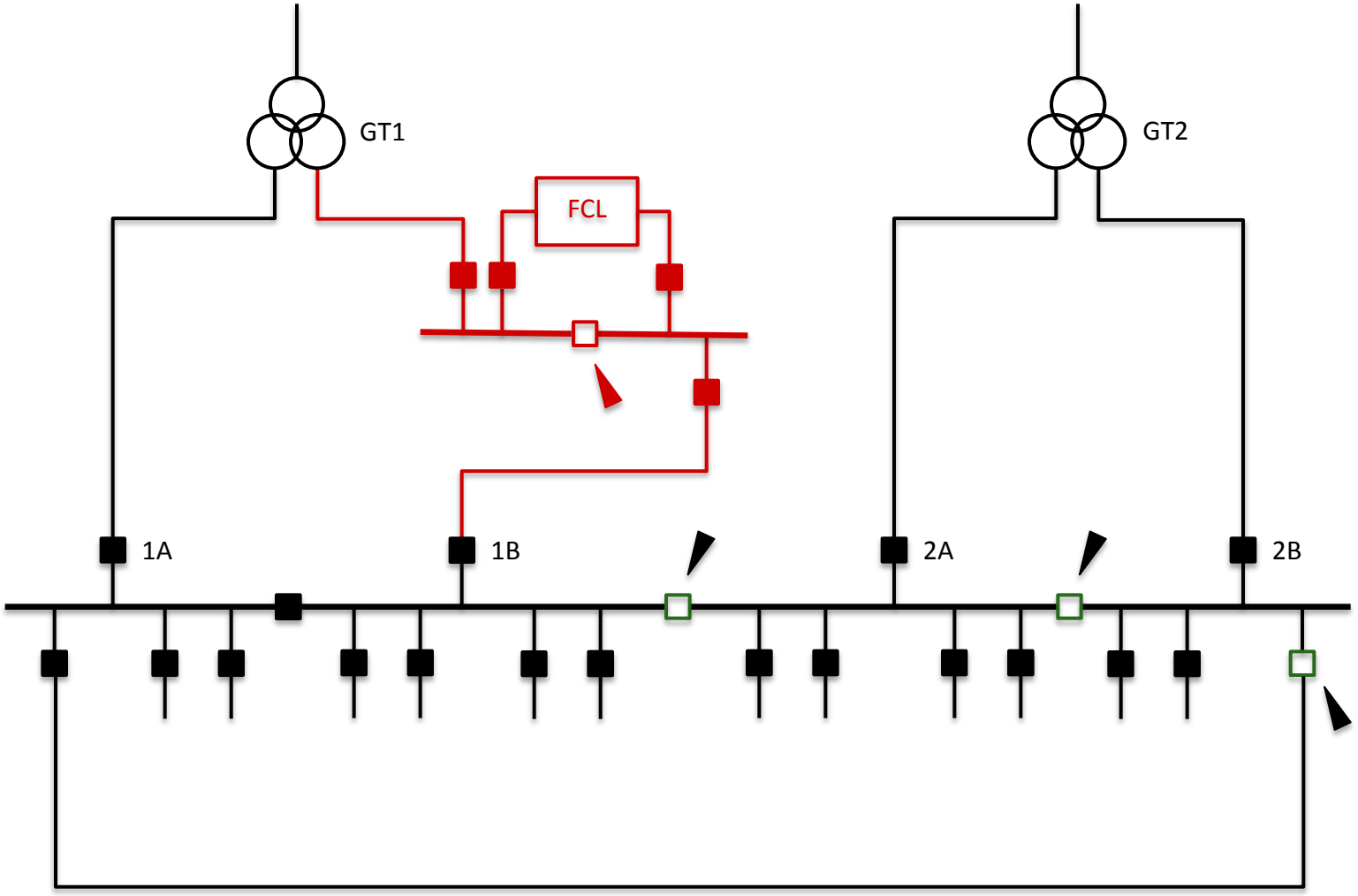
- In series with secondary winding
- Across Bus-Section
- Within Interconnector
- Between Transformers

Network Integration

- Connection of the FCL shall provide the facility to return to the existing network configuration
- FCL can be by-passed for maintenance or during abnormal running

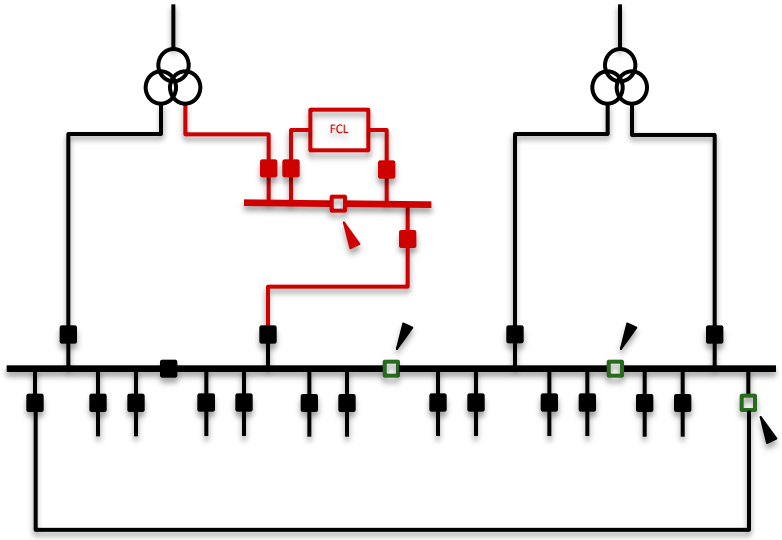


FCL in series with secondary winding



FCL in series with secondary winding

- GT1A and GT1B in parallel
- Consider this option when paralleling two separate transformers is not possible



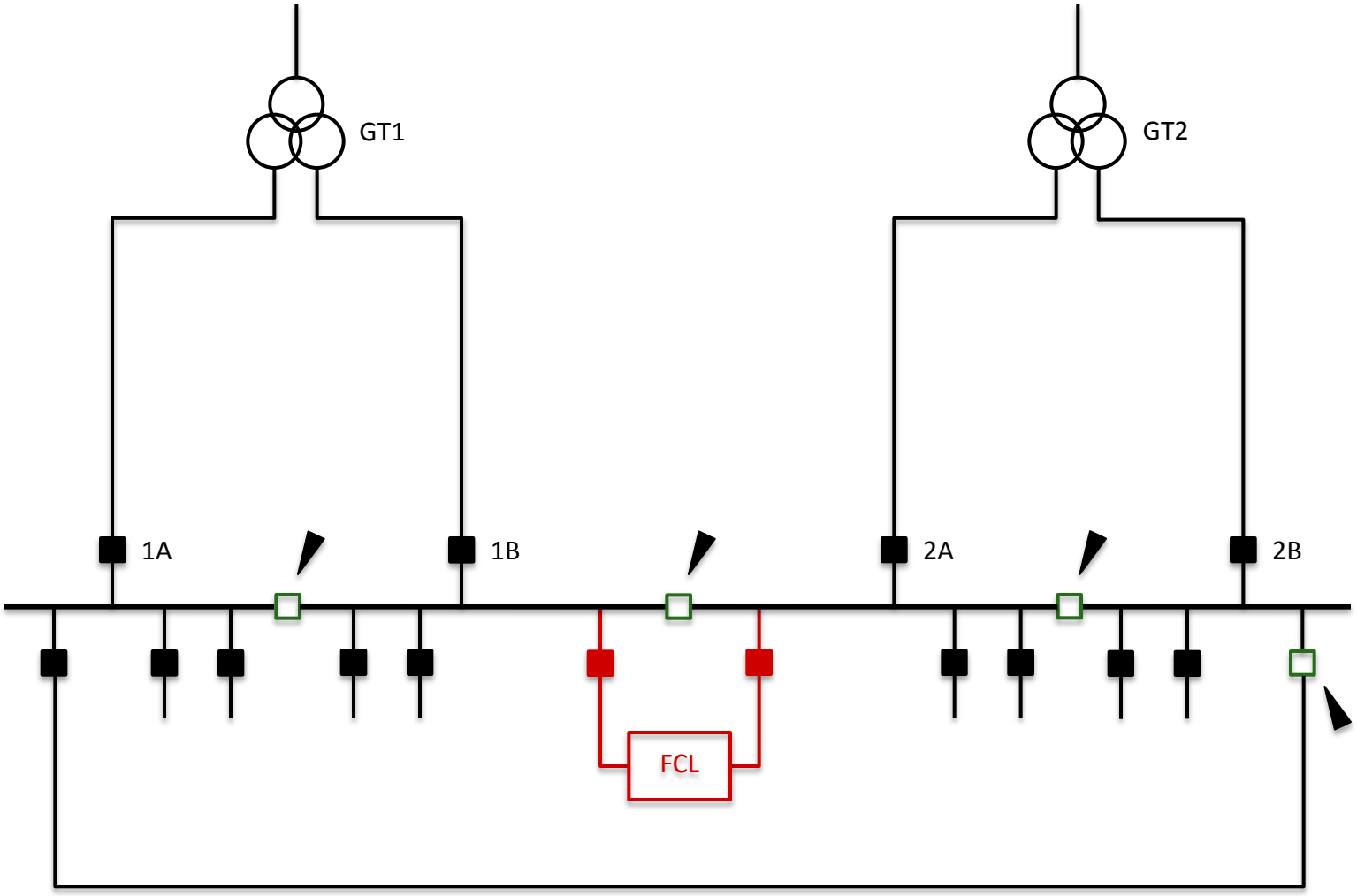
✓ Security of supply

✓ Equipment can be installed off line prior to final connection

✗ Transformer outage required

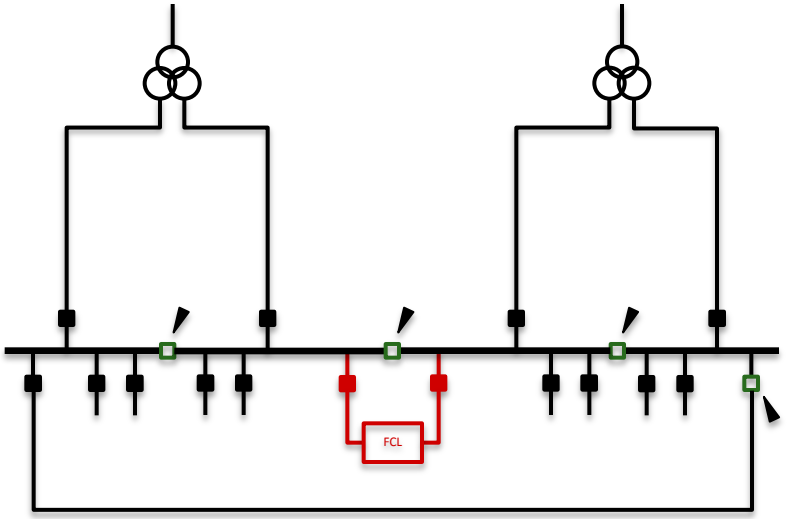
✗ Modifications required to transformer protection

FCL across Bus-Section



FCL across Bus-Section

- GT1B and GT2A in parallel
- Considered for installations where new switchgear is being installed



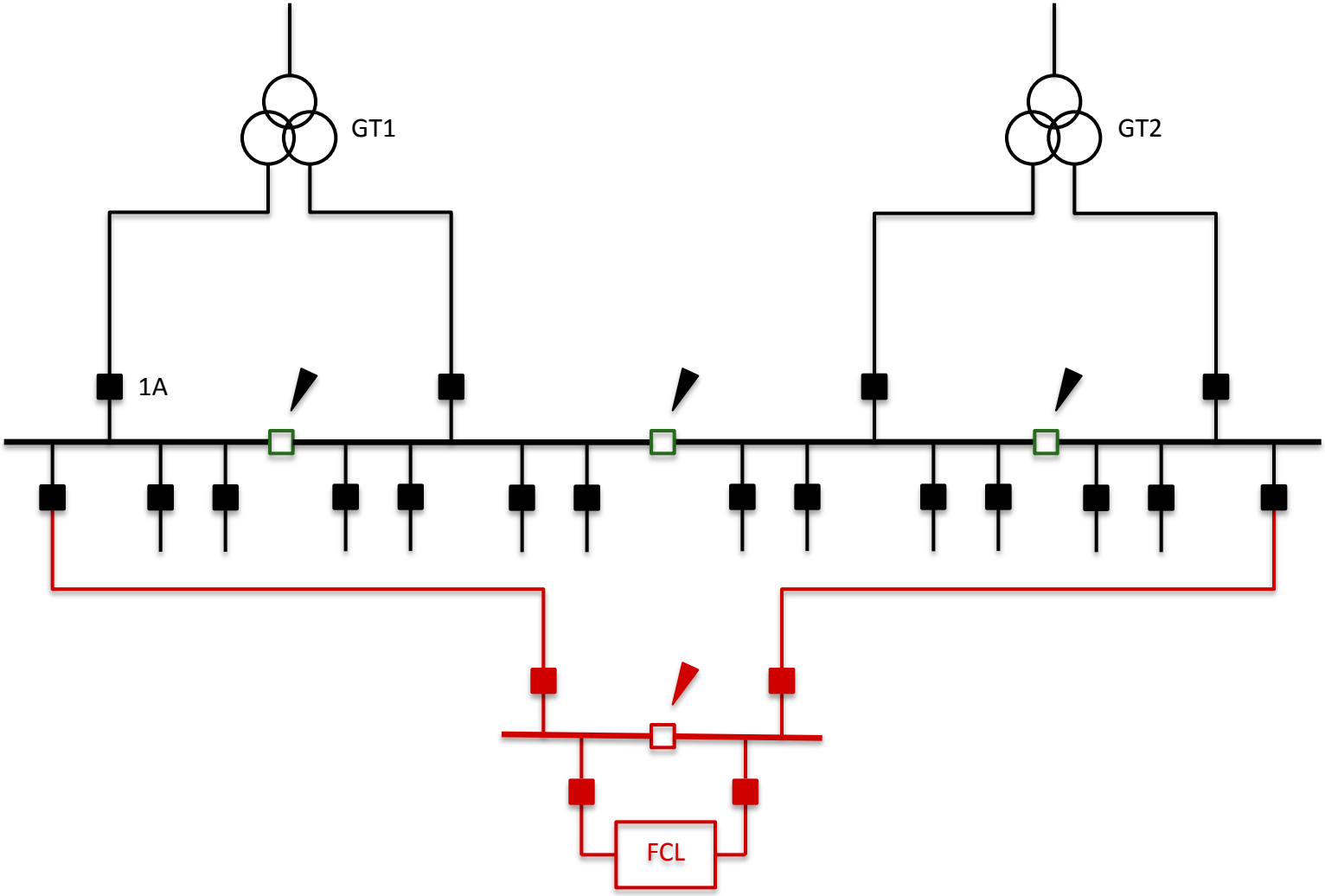
✓ Equipment can be installed off line prior to final connection

✓ Security of supply

✓ Only two circuit breakers required for connection

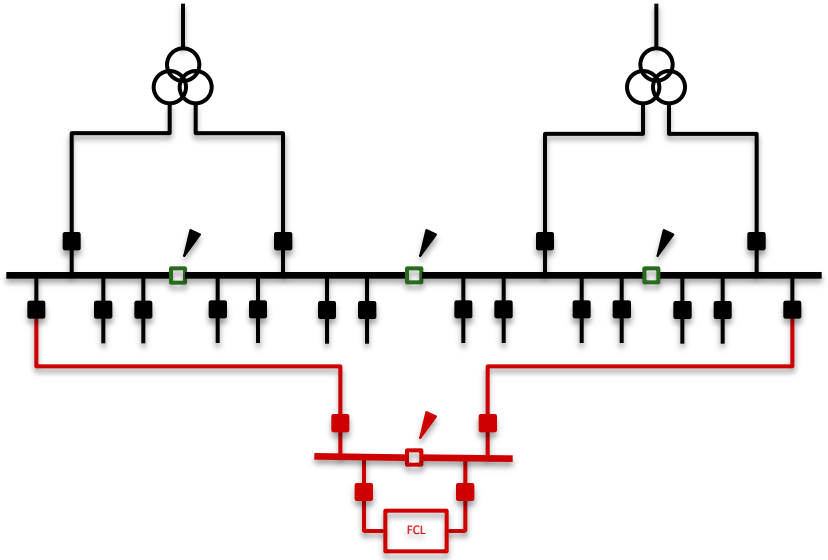
✗ Only applicable where existing switchgear is being replaced

FCL within interconnector



FCL within interconnector

- GT1A and GT2B in parallel
- FCL is connected into the 11kV interconnector

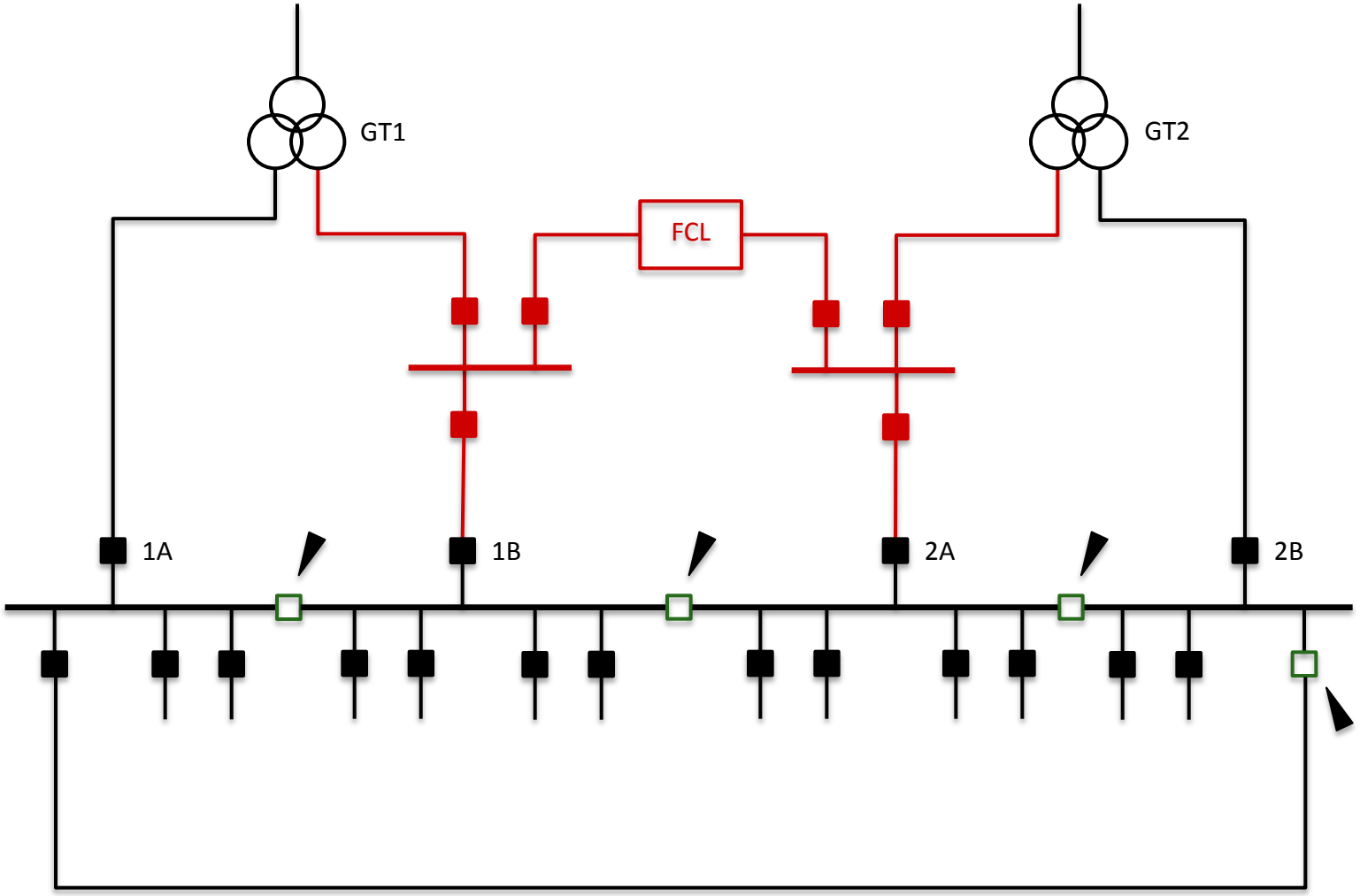


✓ Equipment can be installed off line prior to final connection

✓ Security of supply

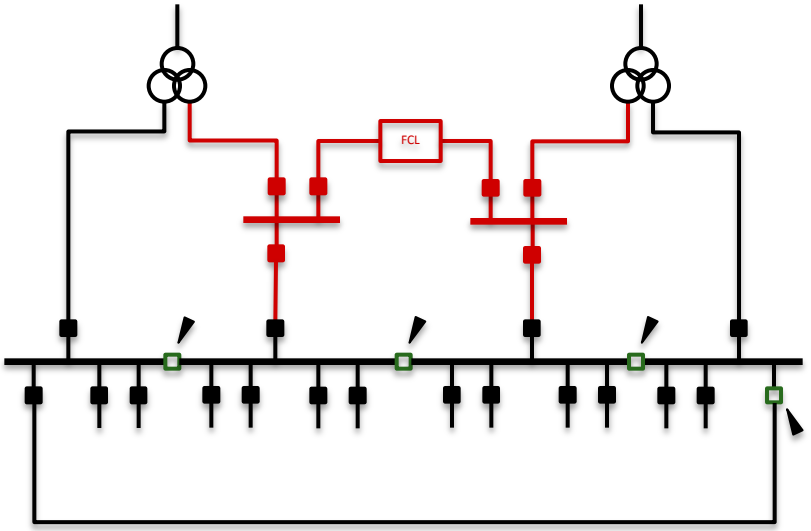
✗ Interconnector (or busbar) outages required for connection

FCL between transformers



FCL between transformers

- GT1B and GT2A in parallel
- Considered generally as a last resort for FCL connection



✓ Equipment can be installed off line prior to final connection

✓ Security of supply

✘ Two transformer outages required for connection

✘ Six circuit breakers required for connection

✘ Complex operating arrangement

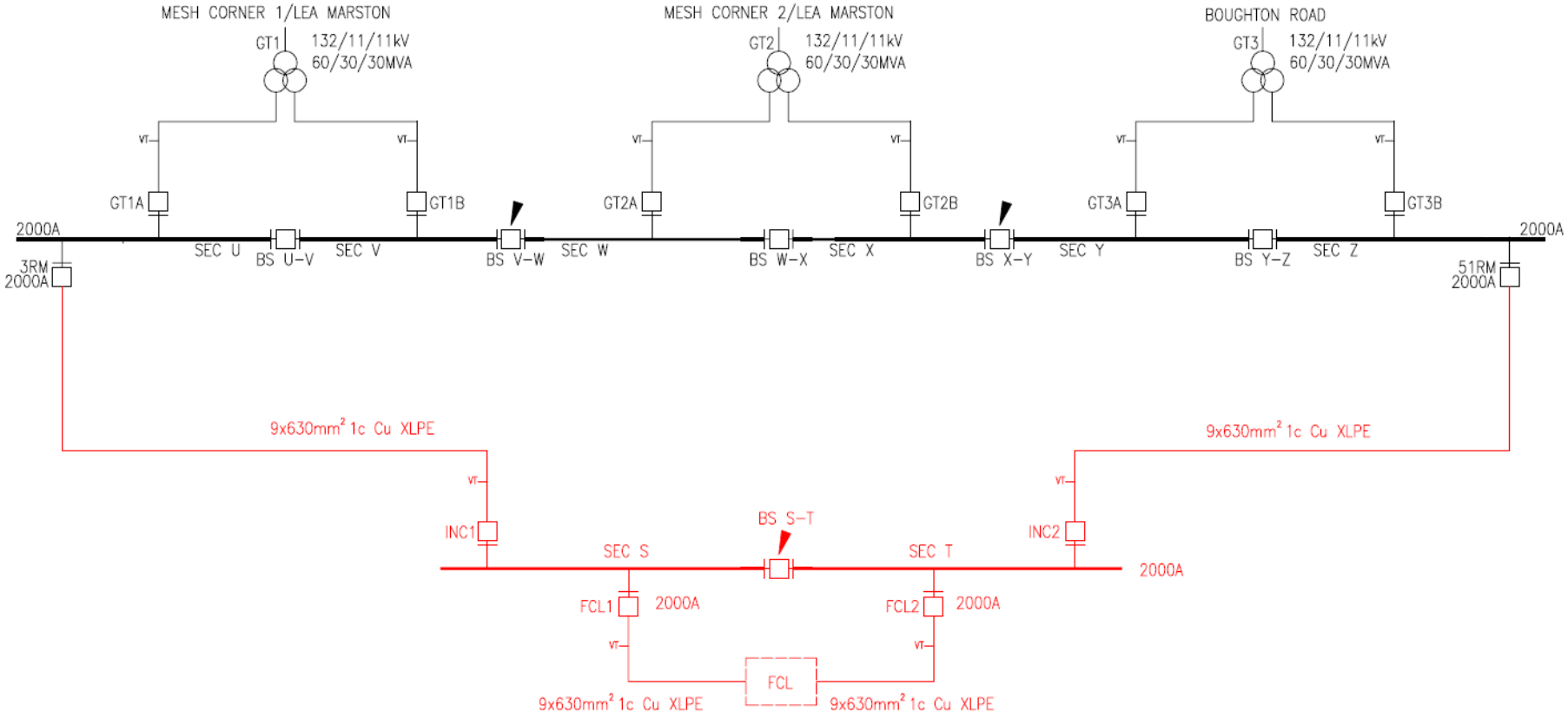
Proposals for FlexDGrid

- 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
- Spare land is available within the substation compound

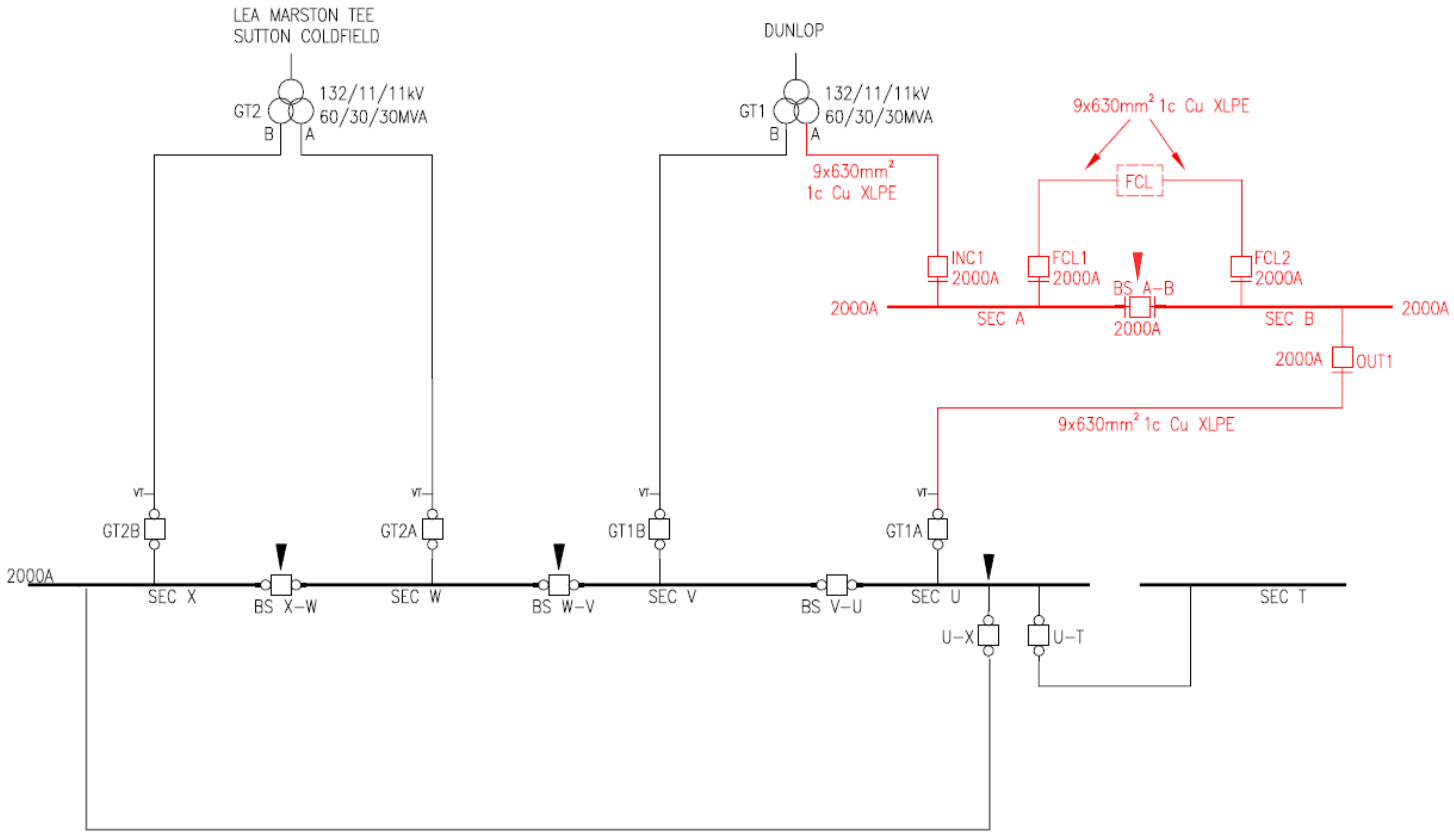
Kitts Green 132/11kV



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’

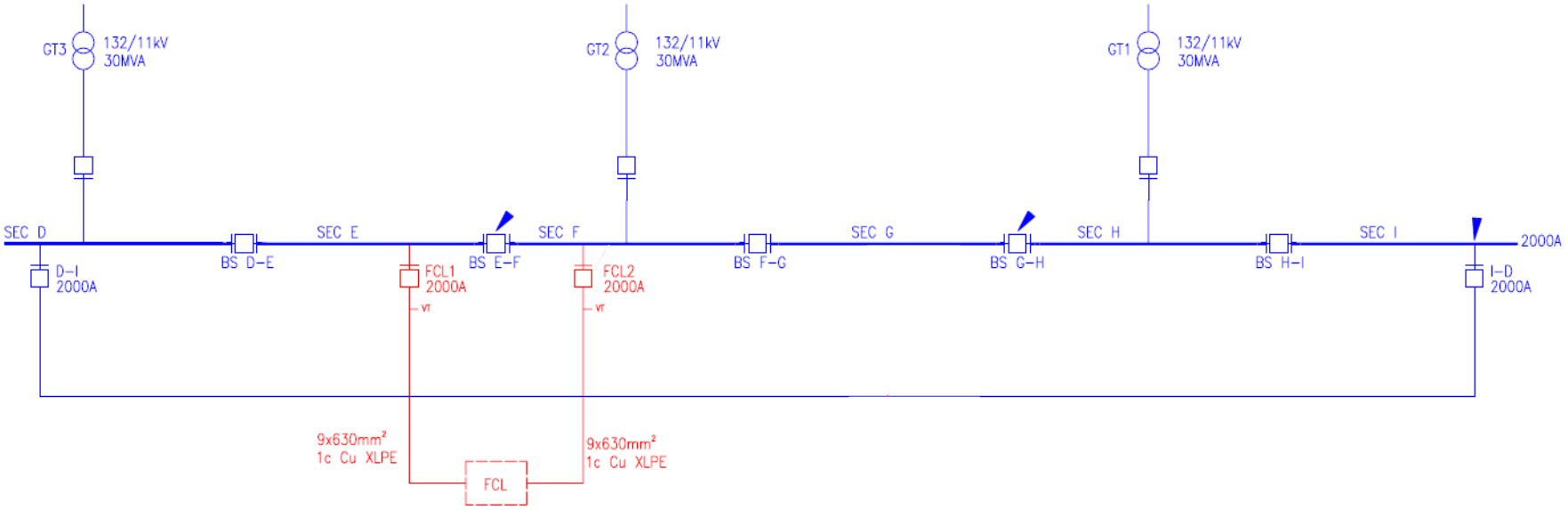
Castle Bromwich 132/11kV



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

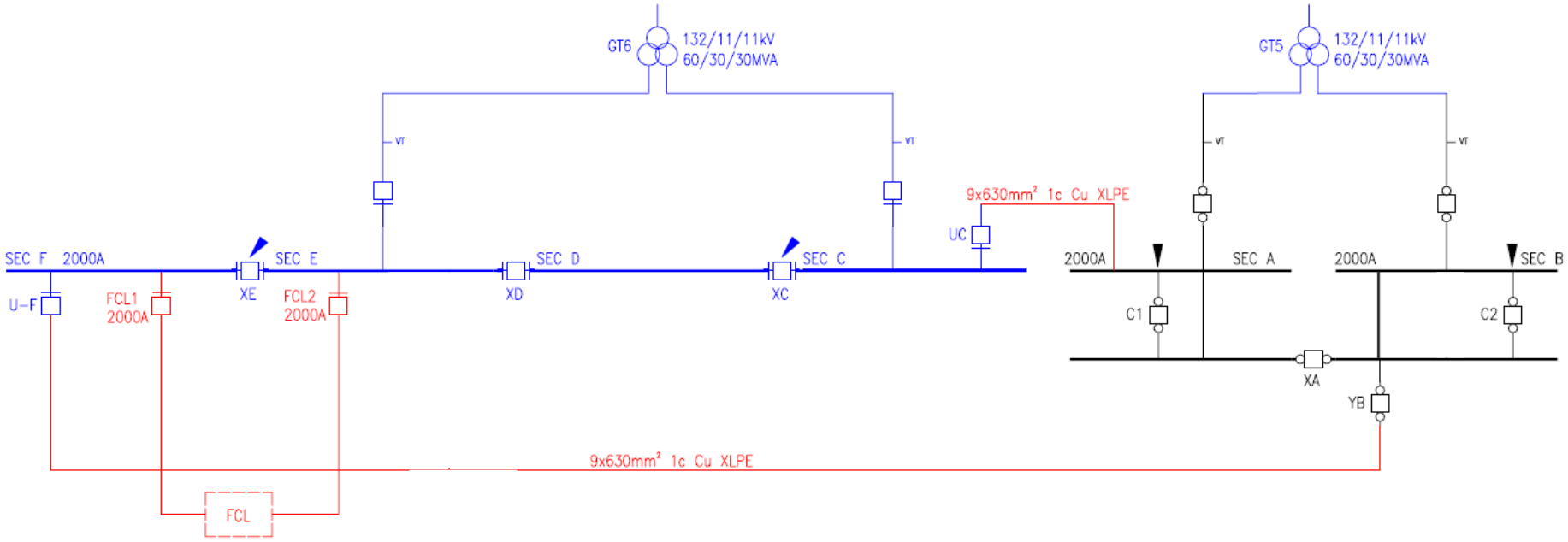
Chester Street 132/11kV



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

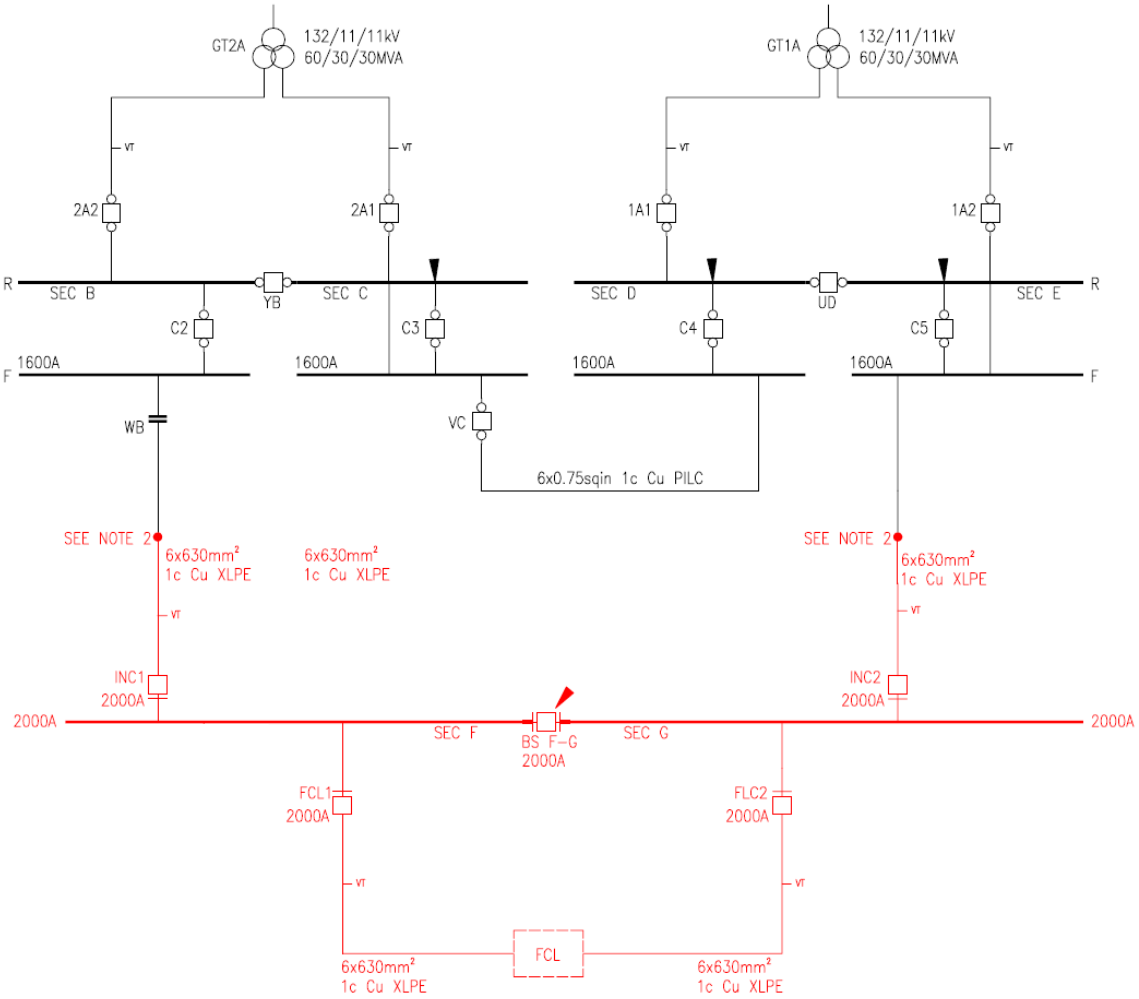
Bournville 132/11kV



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
- Spare land is available within the substation compound

Sparkbrook 132/11kV



Summary

- Principle of Method Gamma
- Existing and emerging methods for fault level mitigation
- Substation Selection Process
- Connection Options for Technologies
- Proposals for FlexDGrid substations

Questions

Lunch and networking

Lodge Room 3

45 minutes

Discussion on FCL installation and implementation

Round table discussion led by:

Jonathan Berry

Break

Sharing best practice options

Round table discussion led by:

Jonathan Berry

Summary of workshop results and next steps

Jonathan Berry

Thank you for joining us

Please complete your feedback form and leave this with us

Have a safe journey home