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Grid Forming Capabilities DSO Update
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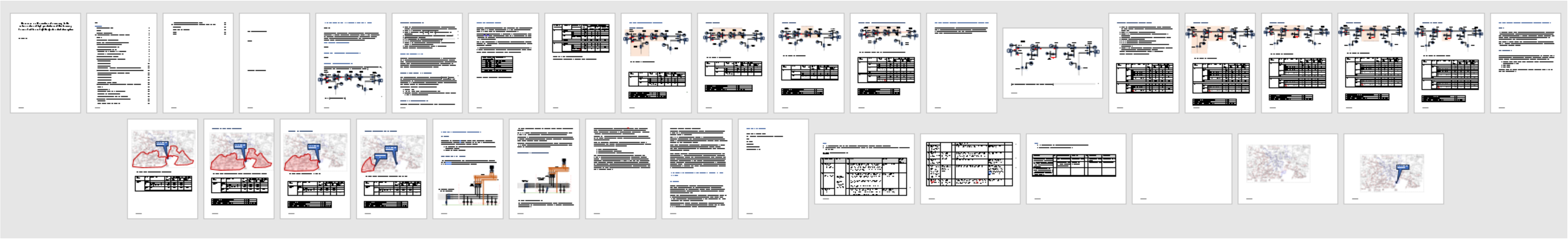
Presentation outline

- Update on guidance document progression
- Emerging technical issue
- Thinking on general Roadmap structure

Evolution of Guidance Document for DSOs on contributing to Roadmaps

- Work continues and it is taking shape
- Structure being refined
- Information is being gathered from EG members on risk analysis mitigations being undertaken in member DSOs
- Detailed sections on islanding risk assessment completed



High level structure of Guidance Document

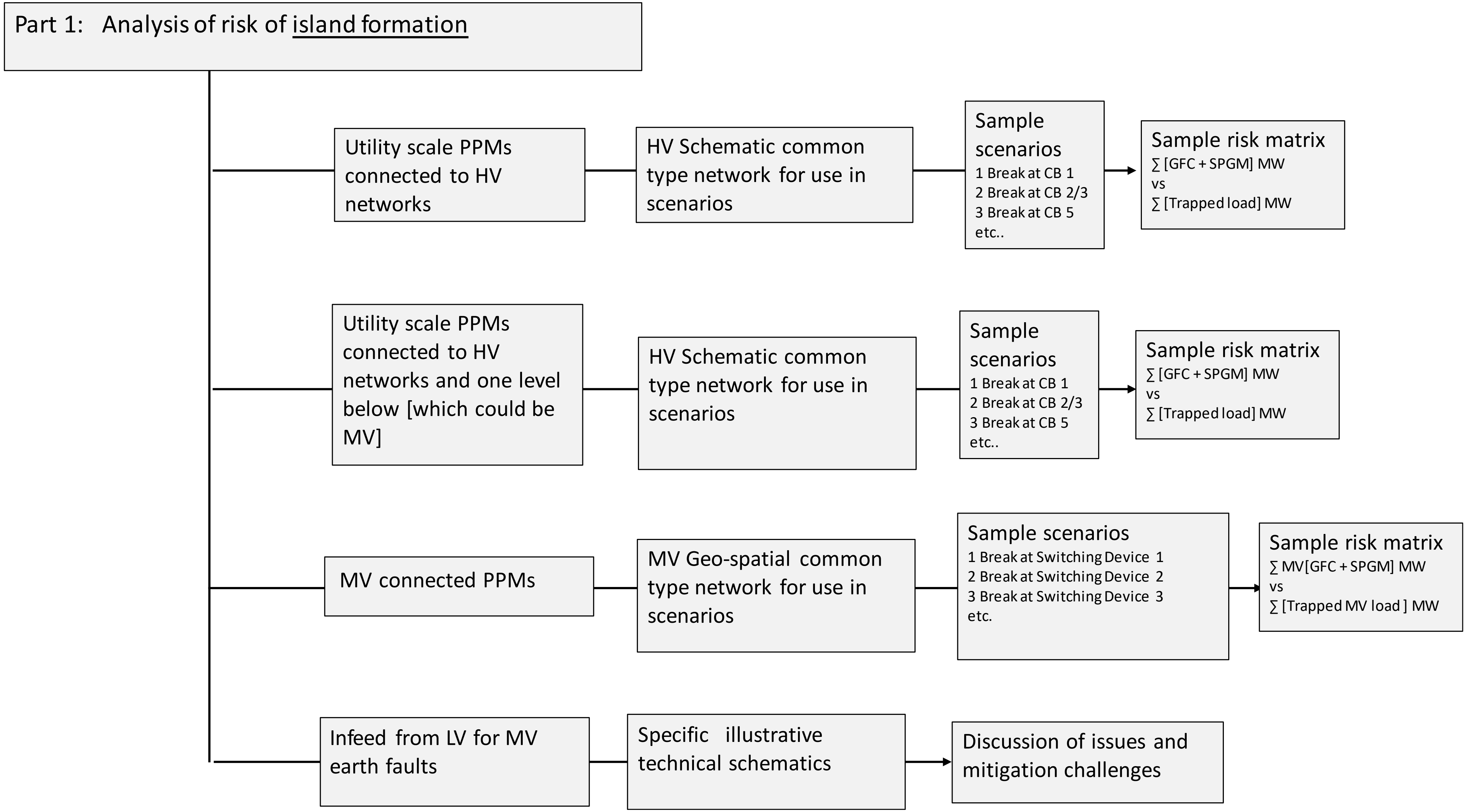
- Introduction scope etc.
- Part 1: Risk analysis of the formation and maintaining of island
- Part 2: Consequences of and potential mitigations for island formation

} Mostly Completed

- Part 3: Risk evaluation templates
- Part 4: Roadmap templates

} Work in progress

Guidance document structure: Part 1 detail



Relative risk of island being maintained

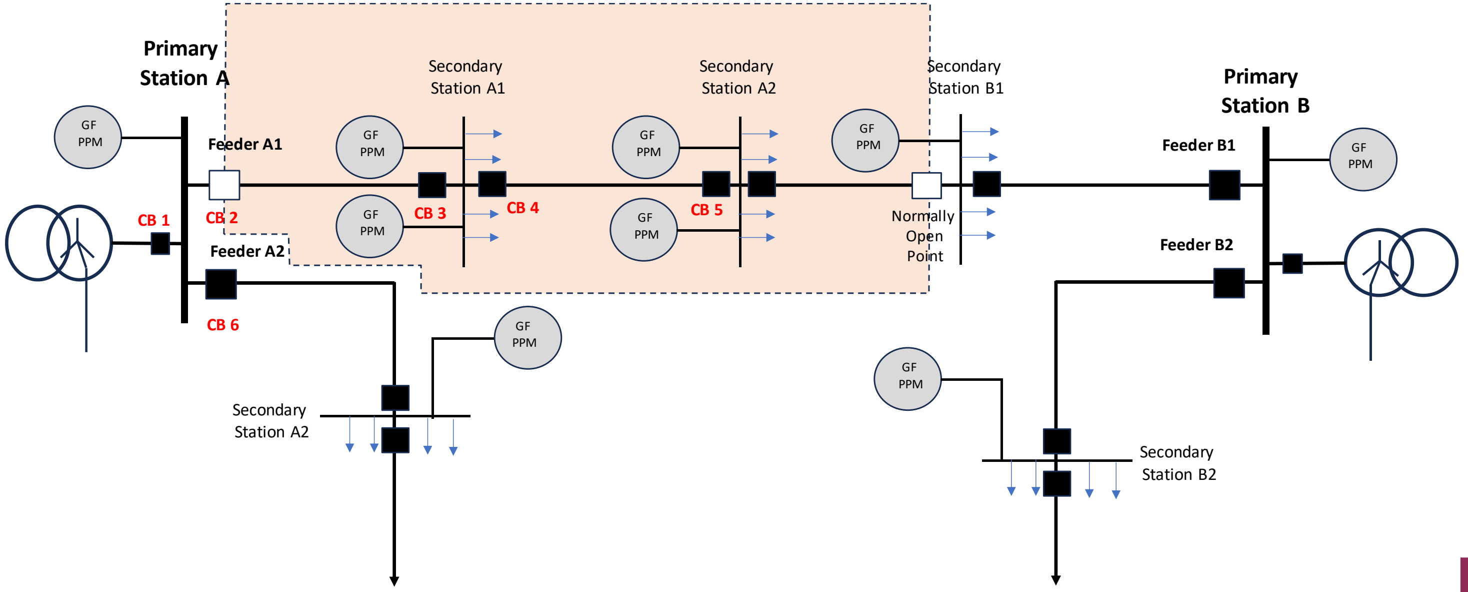
In the illustrative examples described below, for various cases, the ratio or mis-match between the level of island forming generation [SPGMs and/or Grid Forming/Following PPMs], is determined.

This informs the relative risk of the island being maintained, once formed.

Views welcome on these bandings

Generation/Load mis-match [%]	Risk Category
<0 % <20	Extremely low
<20 % <40	Very low
<40 % <60	Low
<60 % <80	Medium
<80 % <100	High
<100 %	Very High

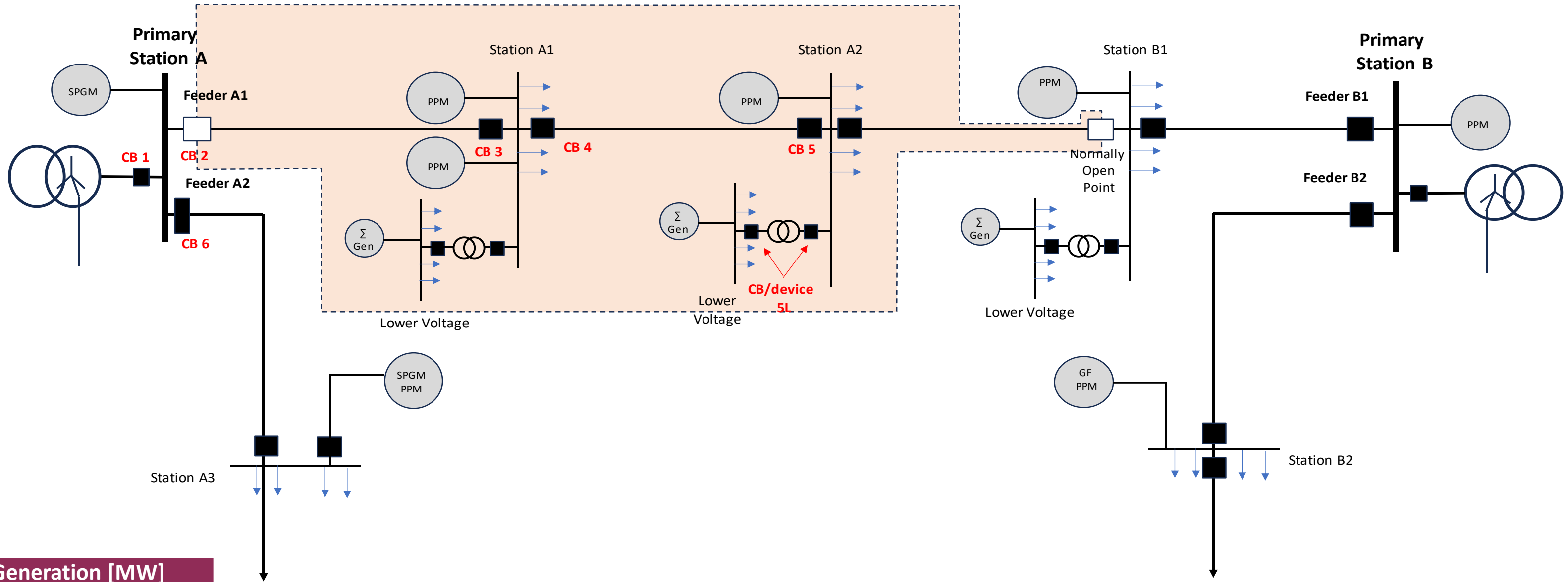
Example 1: HV network



Total summated generation [MW]	18
Total trapped load [MW]	21
Generation/Load mis-match [%]	18/21 = 86
Plausible risk of islanding	Extremely high

Primary Substation	Feeders	Secondary substations fed	Total Min Load [MW]	Total Generation [MW]		
				Grid Following	Grid Forming	Synchronous [SPGMs]
A	Busbar		0			9
	A1	A1	10	4	6	
		A2	8	7	1	
	A3	A3	6	3		2
		Other stations not shown [Ax]	12	4	6	
	Total		36	18	13	11

Example 2: HV and summated lower voltage generation

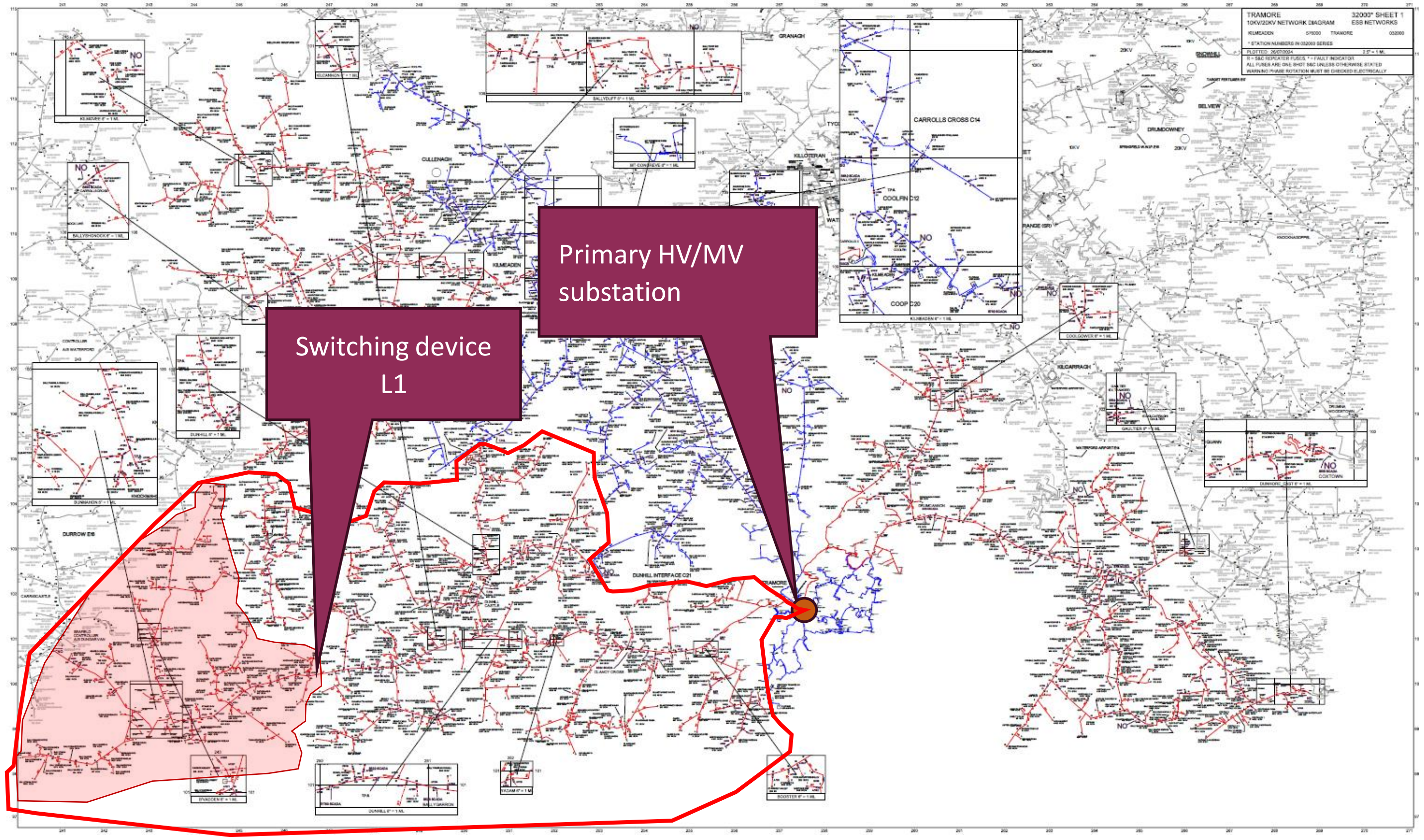


Primary Substation	Feeders	Secondary substations fed	Total Min [MW]	Total Generation [MW] Grid Following	Grid Forming	Synchronous [SPGMs]
A	Busbar		0			9
	A1	A1	10	4	6	
		A1 lower voltage Busbar	3	0.5	4	1
		A2	8	7	1	
		A2 lower voltage Busbar	4	1	4	
	A3	A3	6	3		2
		Other stations not shown [Ax]	12	4	6	
	Total		43	18	13	11
B	Busbar		8	4	4	
	B1	B1	12	5	7	
		B1 lower voltage Busbar	2		5	
	B2	B2	6			11
		Other stations not shown [Bx]	14	4	9	
	Total		40	13	20	11

Total summated generation [MW]	54
Total trapped load [MW]	25
Generation/Load mis-match [%]	54/29 = 186
Plausible risk of islanding	Extremely High

Example 3: MV geo-spatial

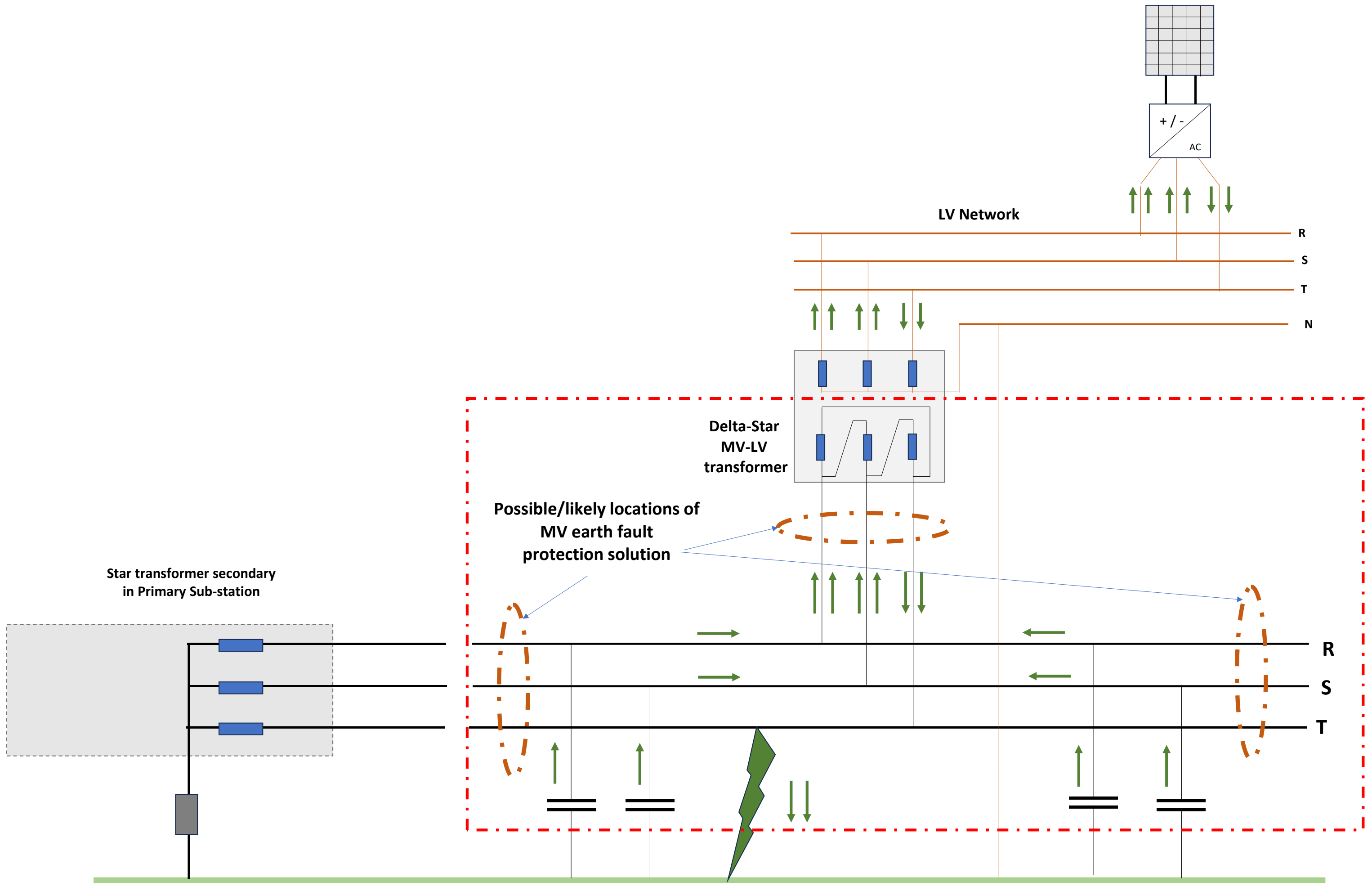
Primary Substation	Feeders	Network sections	Total Min Load [MW]	Total Summated Generation [MW]		
				Grid Following	Grid Forming	Synchronous [SPGMs]
HV/20kV transformer	20kV Busbar					
	Left feeder	Up to switching point L1	1.4	0.94	1.62	
		From L1 to Normally Open point	0.72	0.13	0.18	
	Right feeder	All	2.3	1.41	1.34	0.12
	Total		4.42	2.48	3.14	0.12



Total summated generation [MW]	0.31
Total trapped load [MW]	0.72
Generation/Load mis-match [%]	0.31/0.72 = 13
Plausible risk of islanding	Extremely Low

Infeed to MV earth faults from LV connected PPMs

- This has been identified as a specific challenge.
- Detail discussed



Part 2: Analysis: Consequences of, and potential mitigations for, island formation

General Format of discussions

- Risk
- Impact
- Mitigation
- Post Mitigation Risk
- Concluding Remarks

eg - Risk 1

- For an intact network, earth fault protection is current based using a resistance or directly earthed neutral.
- Islanded network operates as an isolated neutral network. No earth fault protection available in the island, in the event of a single phase to earth fault.

Impact: Unacceptable public safety risk

No	Possible Mitigation	Where	Ref	Discussion	Conclusion	Order of Magnitude
1	To maintain the use of current based protection, form a neutral and earth it.	• At all grid-forming PPMs and SPGMs connected. • At all transformers that have generation [single or summated] connected to its lower voltage side.	A1	Apart from the physical difficulties in forming a star-point and costs etc., there is a fundamental issue with this approach is that if left permanently in place, they would provide multiple parallel paths for fault current in the event of a fault on the intact network. This would severely compromise the effectiveness and operation of current based protection at the primary substation.	This mitigation not considered further.	
2	Form a neutral and earth it via a switch.		A2	The idea here is that the neutral earth switch is normally in the open position and that by some means, the switch would be closed in the event of the island formed. Whilst this would solve the earth fault current splitting issue above, it raises several other issues. It is not clear how it would be known at the site, that the islanding has occurred. An effective island detection system would still be required at each site. Also not clear if there would be sufficient fault current to operate protection reliably.	Technically possible but impractical and extremely expensive for large volumes.	
3	Install residual voltage-based protection.			This would require many components that would normally be associated with a primary HV sub-station, such as; • An earthing transformer with a Voltage Transformer [VT]on the neutral. • A Voltage Transformer [VT] arrangement capable of generating an open delta voltage • Residual voltage relaying A device to trip	Technically possible but impractical and extremely expensive for large volumes.	

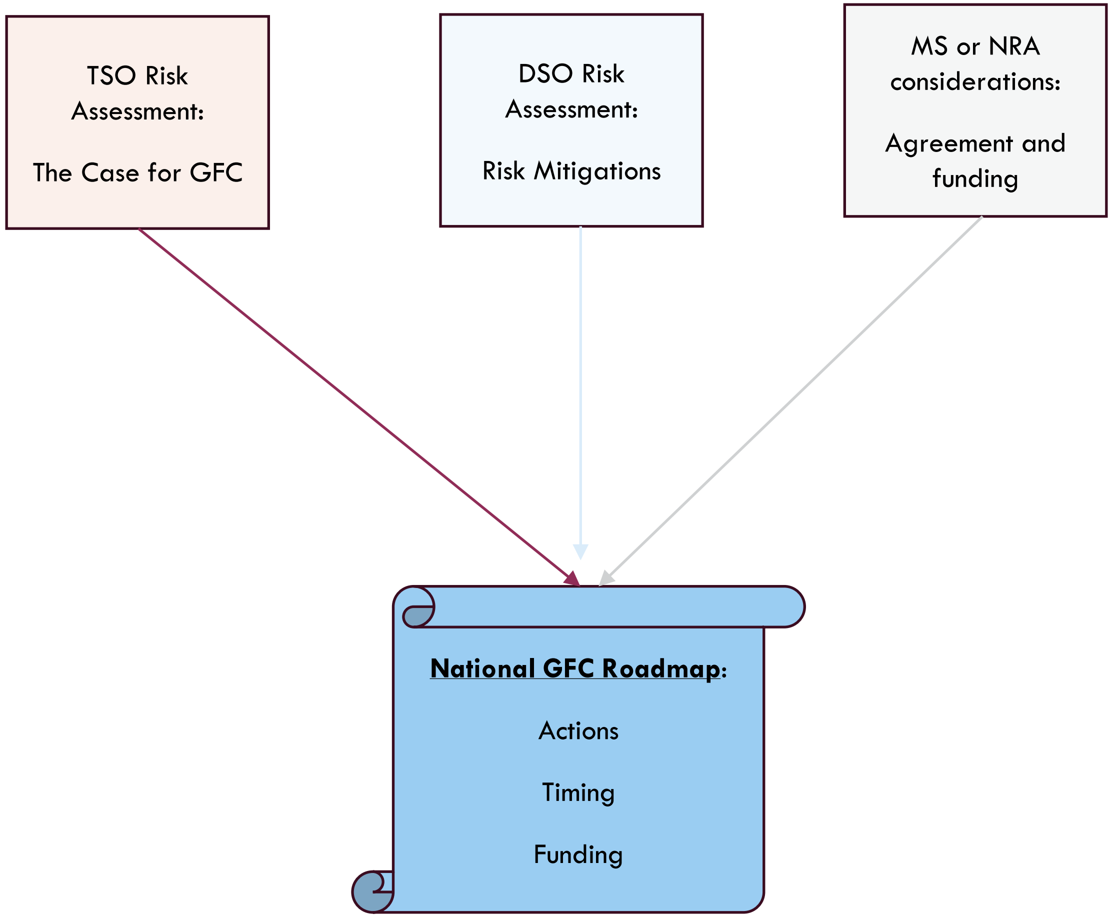
Emerging new issues:

1. The viability of Type A and Type B Grid Forming PPMs [GFM] in supporting islands given they do not have mandated energy stores to provide inertia
2. The extent to which Grid Forming plant will also support Grid Following [GFL] plant when they are islanded together.

- For case 1 the lack of inertia could mean that GFM converters are not capable of transitioning to a stable island because the frequency moves too far before the active power output can be varied to stabilize the frequency.
- For case 2 we need to be clear about how GFL converters will respond to islands formed by GFM converters – there seems no reason to assume that the GFL will "fall over" as the GFM converters are continuing to supply a 50Hz voltage to the GFL terminals.
- These impact the islanding risk analysis above.

General Roadmap structure - 1

- The work in this document will inform the DSO component of the Roadmap
- There will also be TSO inputs and ultimately,
- MS or NRA agreement.



General Roadmap structure - 2

- One possible example of early formative thinking on this.
- Possible high level Roadmap structure

National GFC Roadmap Template

1 Scope and purpose

Short section stating the issues that are identified and resolved in this document, and its national status, governance etc

2 Background and development

Short description of the development of this document, including the analysis undertaken, its rigour etc, and support from stakeholders.

3 Analysis

More detail to be provided (and probably in appendices) of the risk analysis, matrices etc, broken down at an appropriate level of detail. This is where the main case should be made, by the TSO(s) for the introduction of grid forming. This document is probably going to be **the** formal record – so it will need to be comprehensive.

4 Identified risks

This section to be based on the analysis undertaken to develop the national roadmap

4.1 Whole system risks that grid forming mitigates

TSO input.

4.2 Uncontrolled islands

4.2.1 Protection Operation

4.2.2 Interaction with other network equipment

4.2.3 Effect on quality of supply

4.2.3.1 Voltage quality
4.2.3.2 Reliability/Interruptions

4.3 Stability

4.4 Other?

5 Mitigations

These might be best split into two simple classes as in this example, but other divisions of the mitigations might be more appropriate in some member states, eg by regulatory treatment.

5.1 Changes to Operational Practice

5.2 New/modified equipment and/or technologies

6 Regulatory considerations

A statement of intent, ideally written by the NRA, on how regulation will support the implementation of the road map.

7 Future work

Including the revision of the road map, probably driven by both time, and also by events/developments.

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Questions?