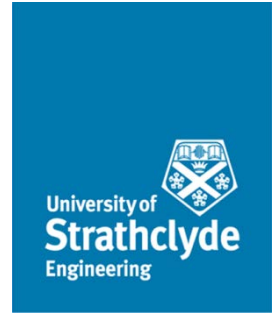


# Risk Assessment of Loss of Mains Protection

**18 March 2013**

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Glasgow, UK  
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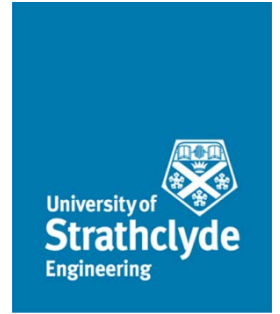
# Outline



- Revised work plan and methodology
- Initial DNO data
- Additional questions and data requirements
- Progress so far and completion date
- Other generation technologies (Phase II)

# Phase I – Scope of work

# WP1 - Simulation based assessment of Non Detection Zone (NDZ)

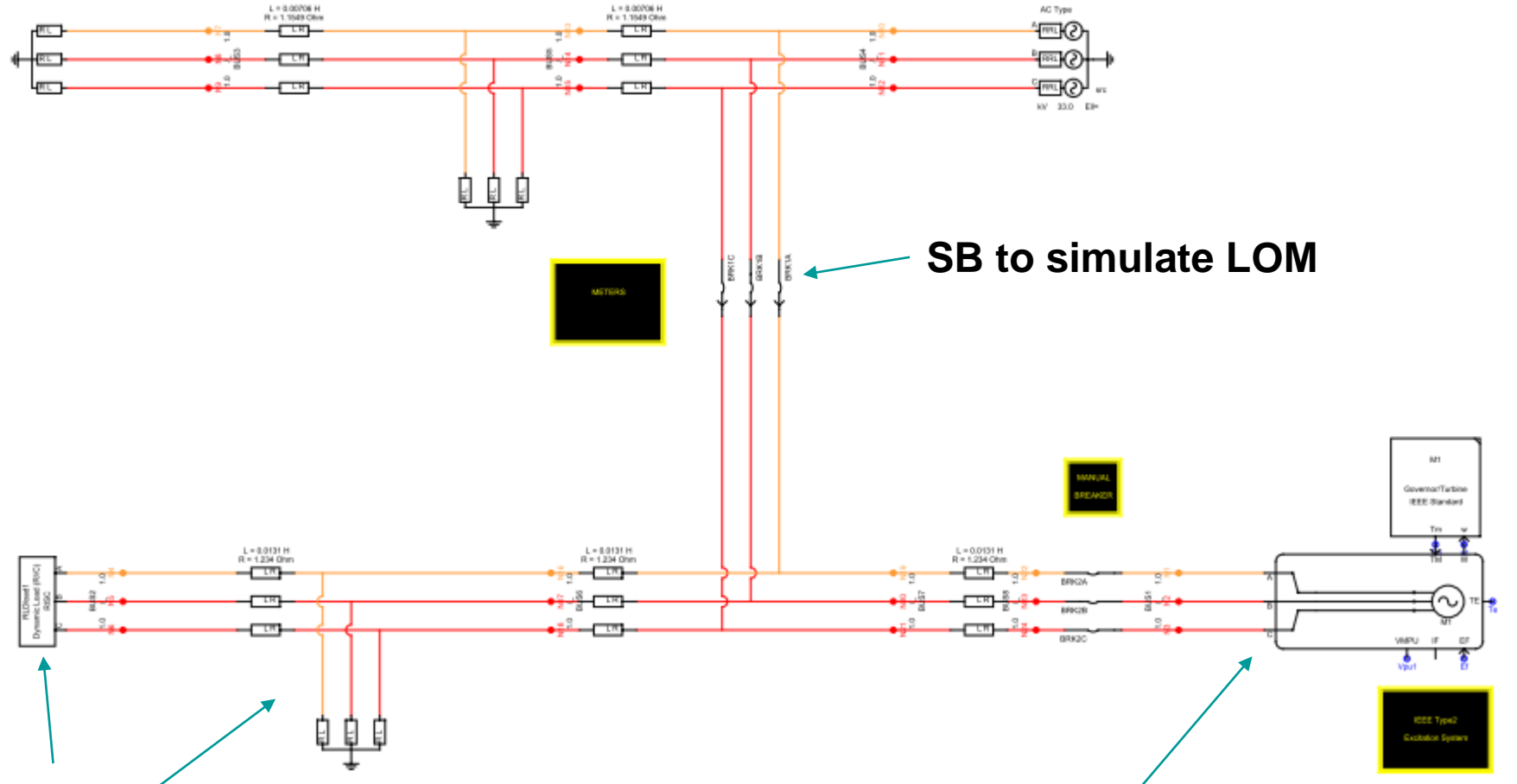


- RTDS real-time model of 30MVA machine connected to 33kV level (3MVA also machine considered for 'spot' checks)
- Laboratory hardware testing using a commercial relay with 8 setting options
- Load modelling as fixed impedance and fixed power
- Generator control considered as P/pf and P/V

Setting Option	ROCOF [Hz/s]	Time Delay [s]	Dead Band applied
1	0.5	0.0	No
2	0.5	0.5	No
3	1.0	0.0	No
4	1.0	0.5	No
5	0.5	0.0	Yes
6	0.5	0.5	Yes
7	1.0	0.0	Yes
8	1.0	0.5	Yes

# RTDS Model – network diagram

**Grid infeed**



**SB to simulate LOM**


**Adjustable loads**

**Generator with controllers**

# RTDS Model – control panel

Generator control


LockFree



Free


**1**

CTRLmode



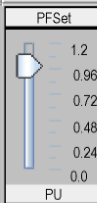
**0**

QPF



**0**

PFSet

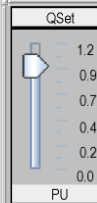


1.2  
0.96  
0.72  
0.48  
0.24  
0.0

PU

**1.0**

QSet



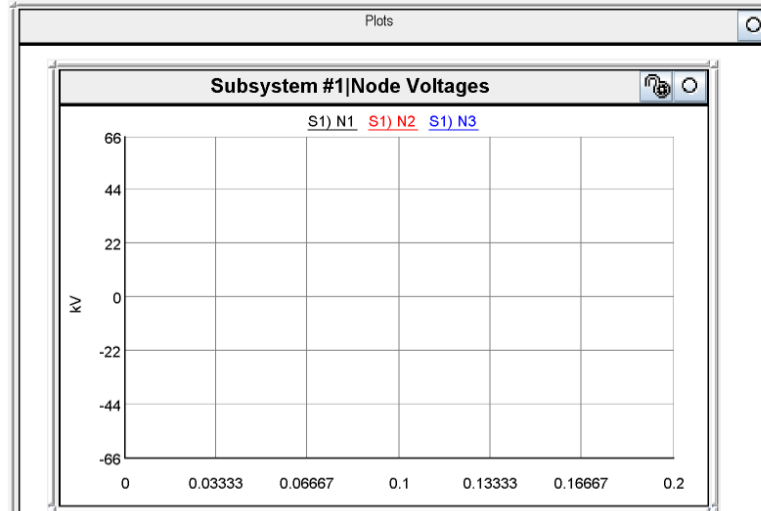
1.2  
0.96  
0.72  
0.48  
0.24  
0.0

PU

**1.0**


PMACH1	QMACH1	LOADANG1	ROTANG1
-200.0	-200.0	-2.0	-10.0

wt	Te	Tm	Vpu1
-500.0	-2.0	0.0	-2.0



Load control

Pset

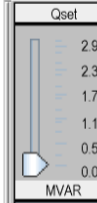


5.0  
4.02  
3.04  
2.06  
1.08  
0.1

MW

**3.0**

Qset




2.95  
2.36  
1.77  
1.18  
0.59  
0.00

MVAR

**0.1**


BRK control

CLOSE1




**0**

CLOSE2




**0**

OPEN1




**0**

OPEN2




**0**

BRK1



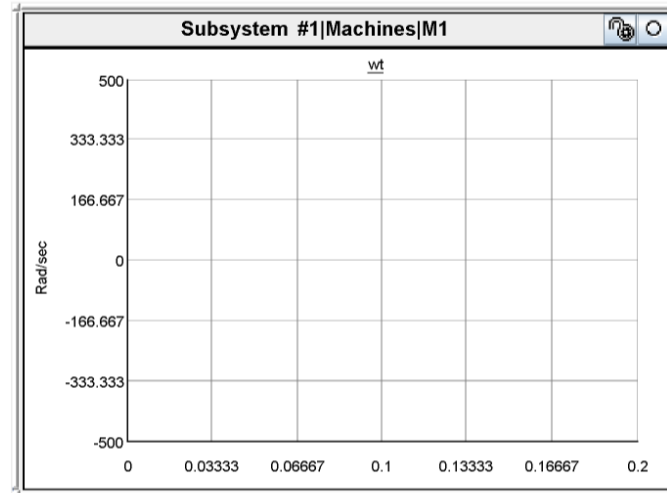
BRK2



Operational mod

PSYSPU
<b>0.0</b>

QSYSPU
<b>0.0</b>



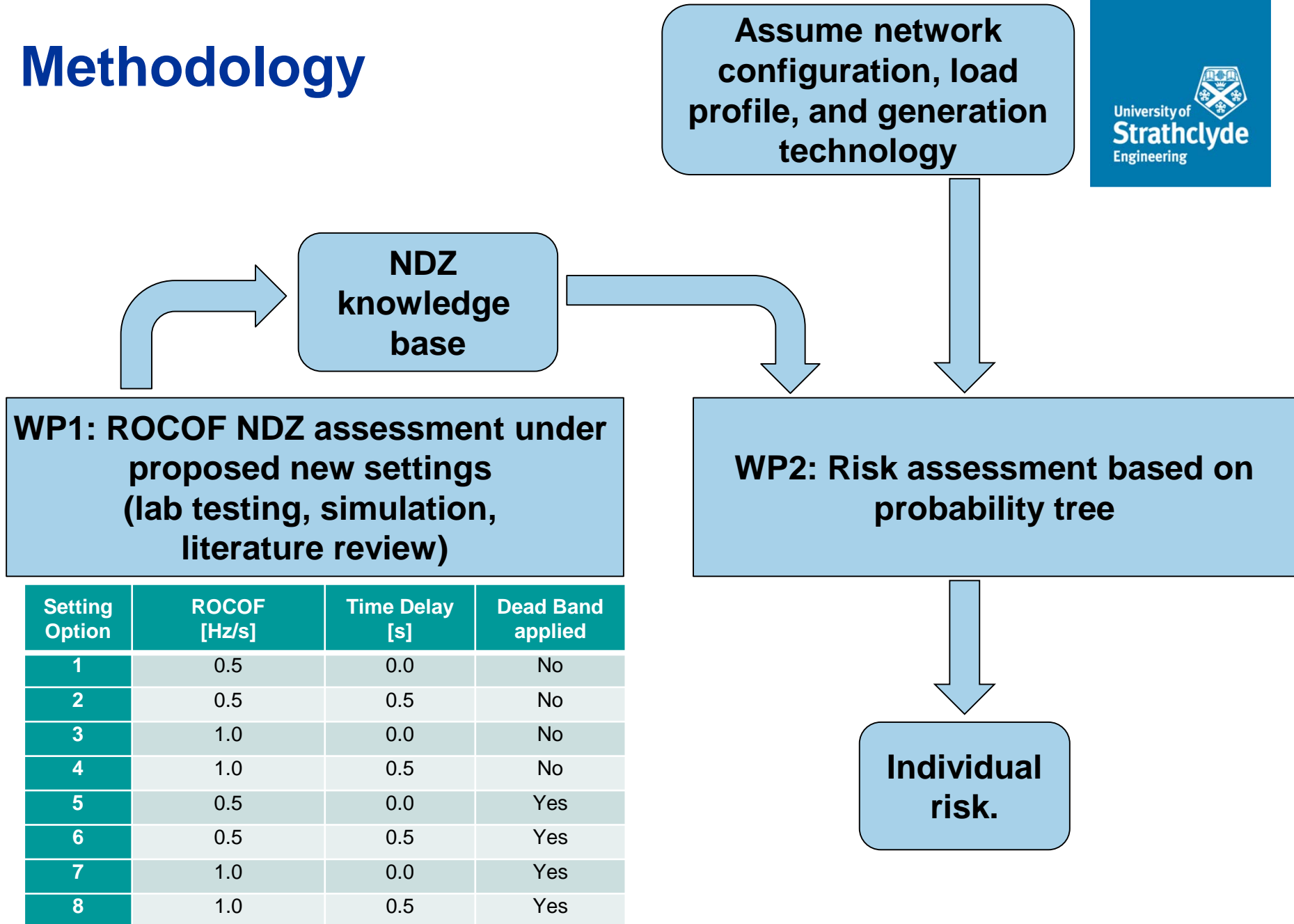
## WP2 – Risk level calculation at varying NDZ

- Generation range considered 5MW – 50MW
- UK data
  - DG Generation statistics
  - Load profiles acquired from the utilities
  - Island formation configuration and statistics
- Overall risk of undetected islanding condition persisting longer than acceptable limit (e.g. 3s) will be established.

# Phase I – Methodology



# Methodology



**WP1: ROCOF NDZ assessment under proposed new settings (lab testing, simulation, literature review)**

Setting Option	ROCOF [Hz/s]	Time Delay [s]	Dead Band applied
1	0.5	0.0	No
2	0.5	0.5	No
3	1.0	0.0	No
4	1.0	0.5	No
5	0.5	0.0	Yes
6	0.5	0.5	Yes
7	1.0	0.0	Yes
8	1.0	0.5	Yes

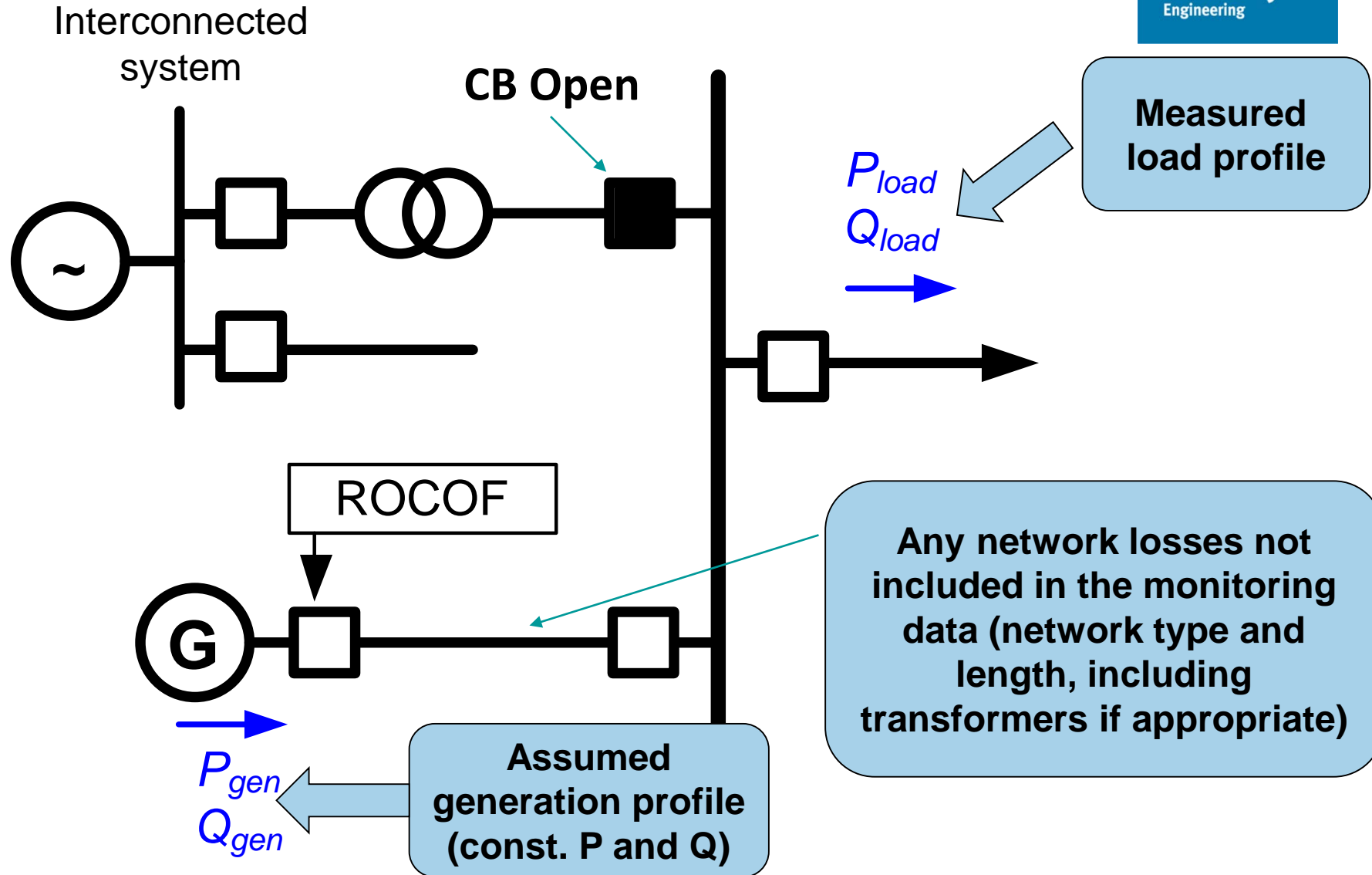
**Assume network configuration, load profile, and generation technology**

**NDZ knowledge base**

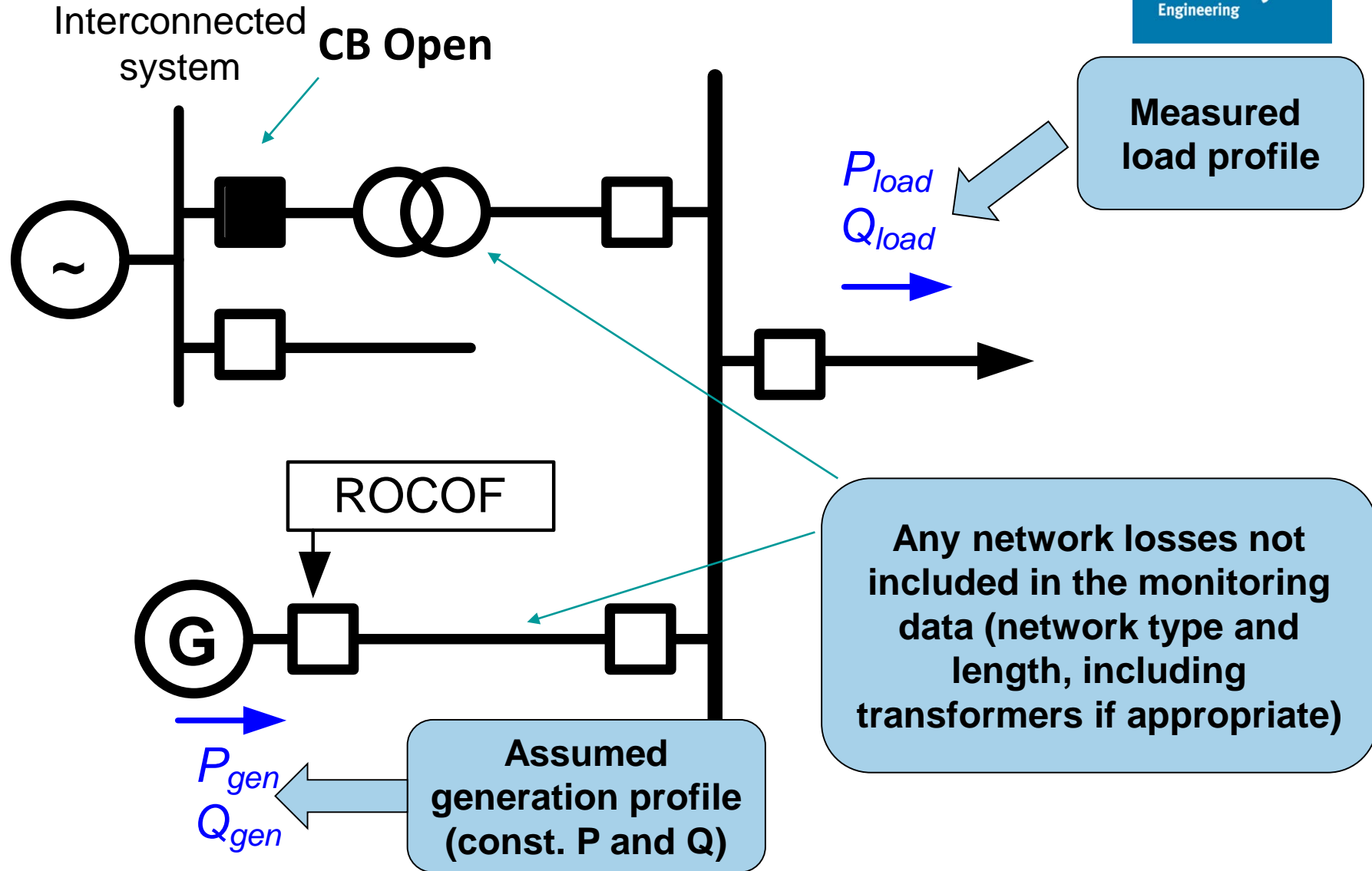
**WP2: Risk assessment based on probability tree**

**Individual risk.**

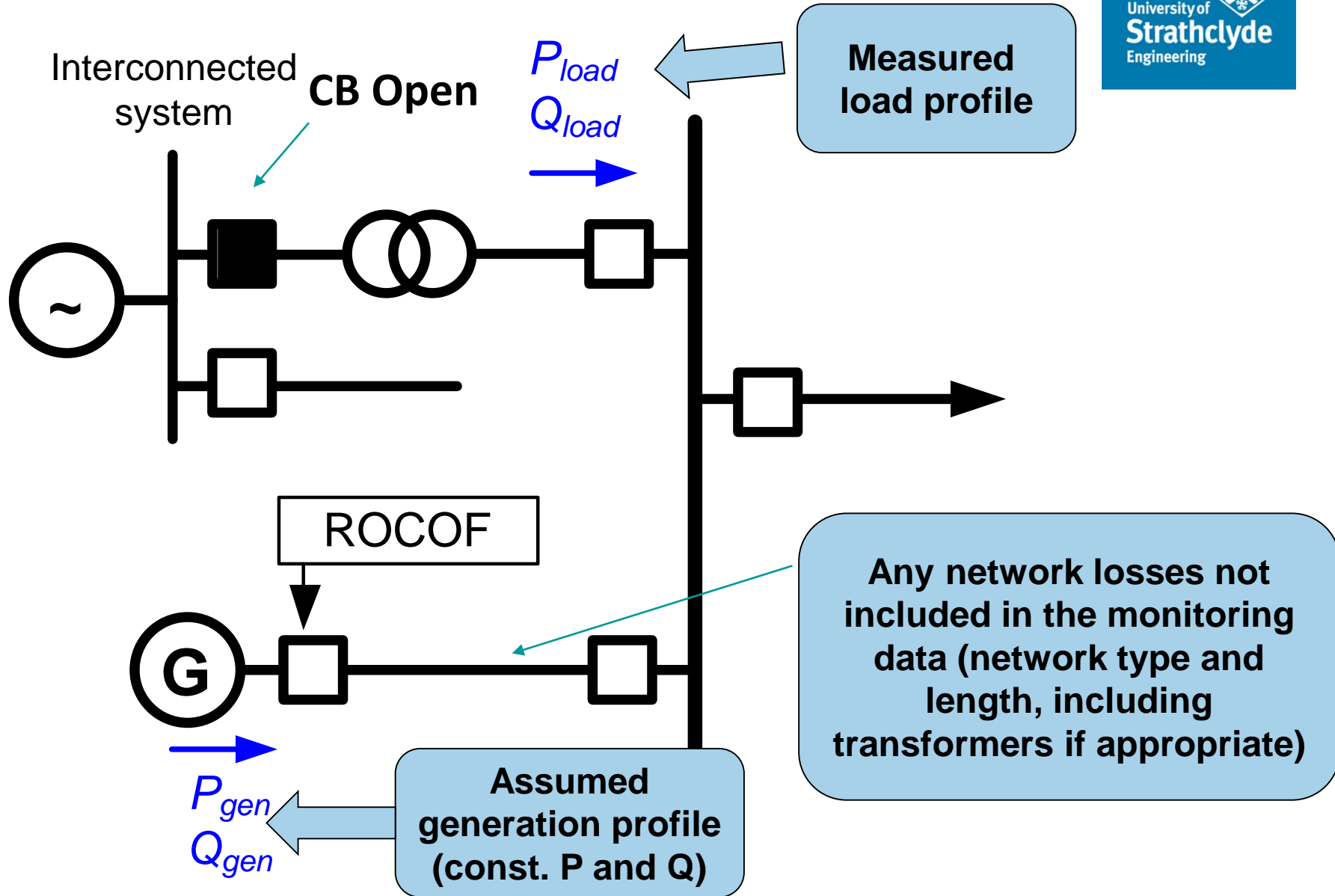
# Network model for the probability tree



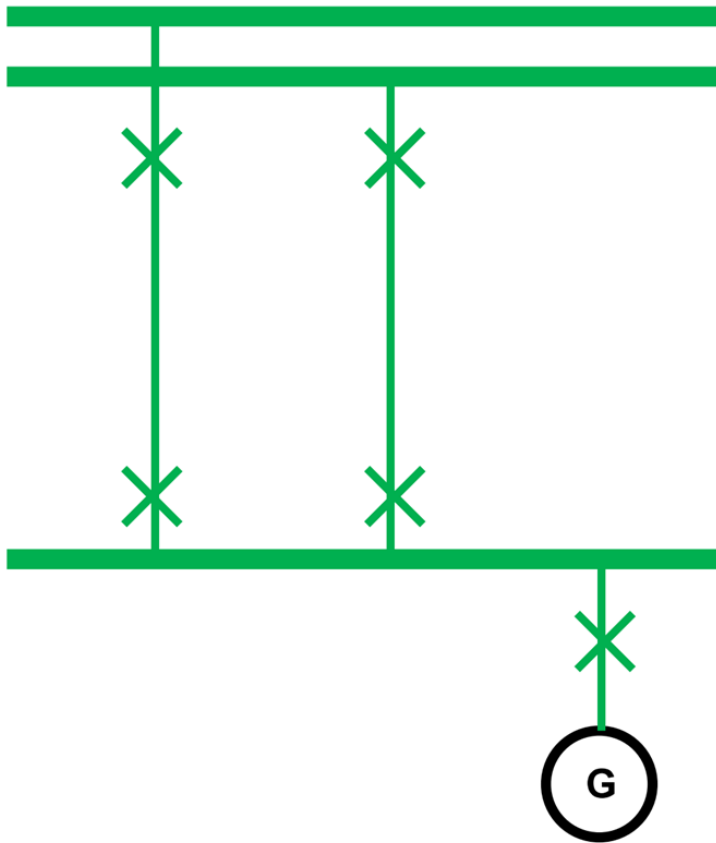
# Network model for the probability tree



# Network model for the probability tree



# Island formation options

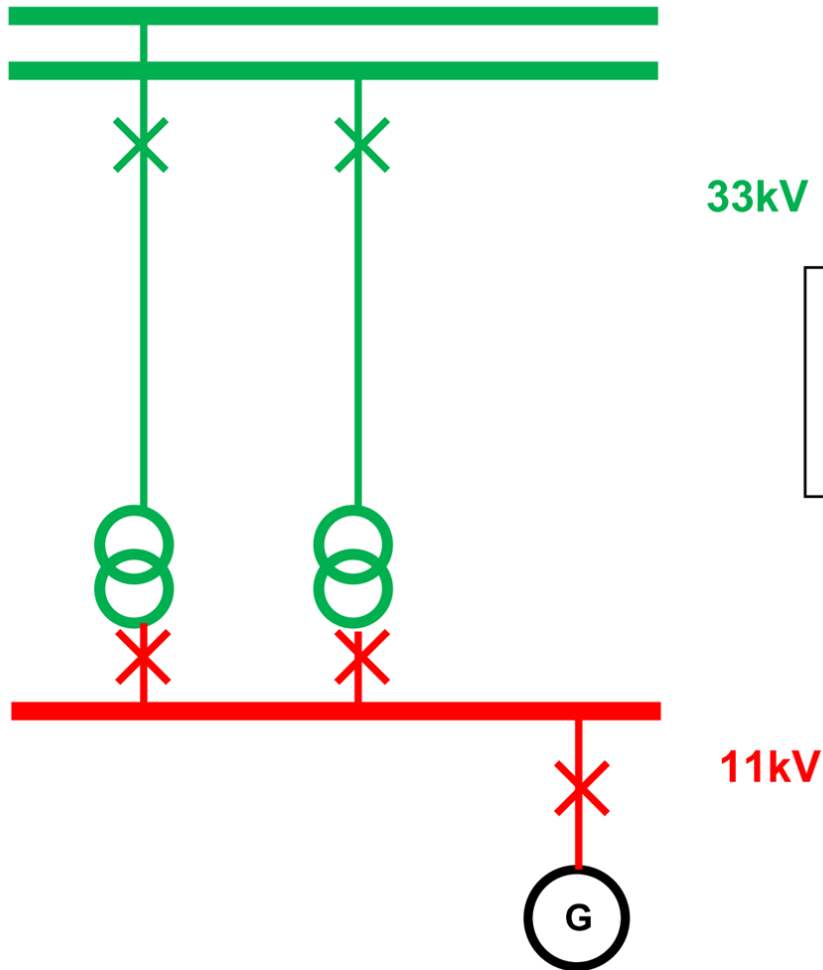


33kV

Type 1

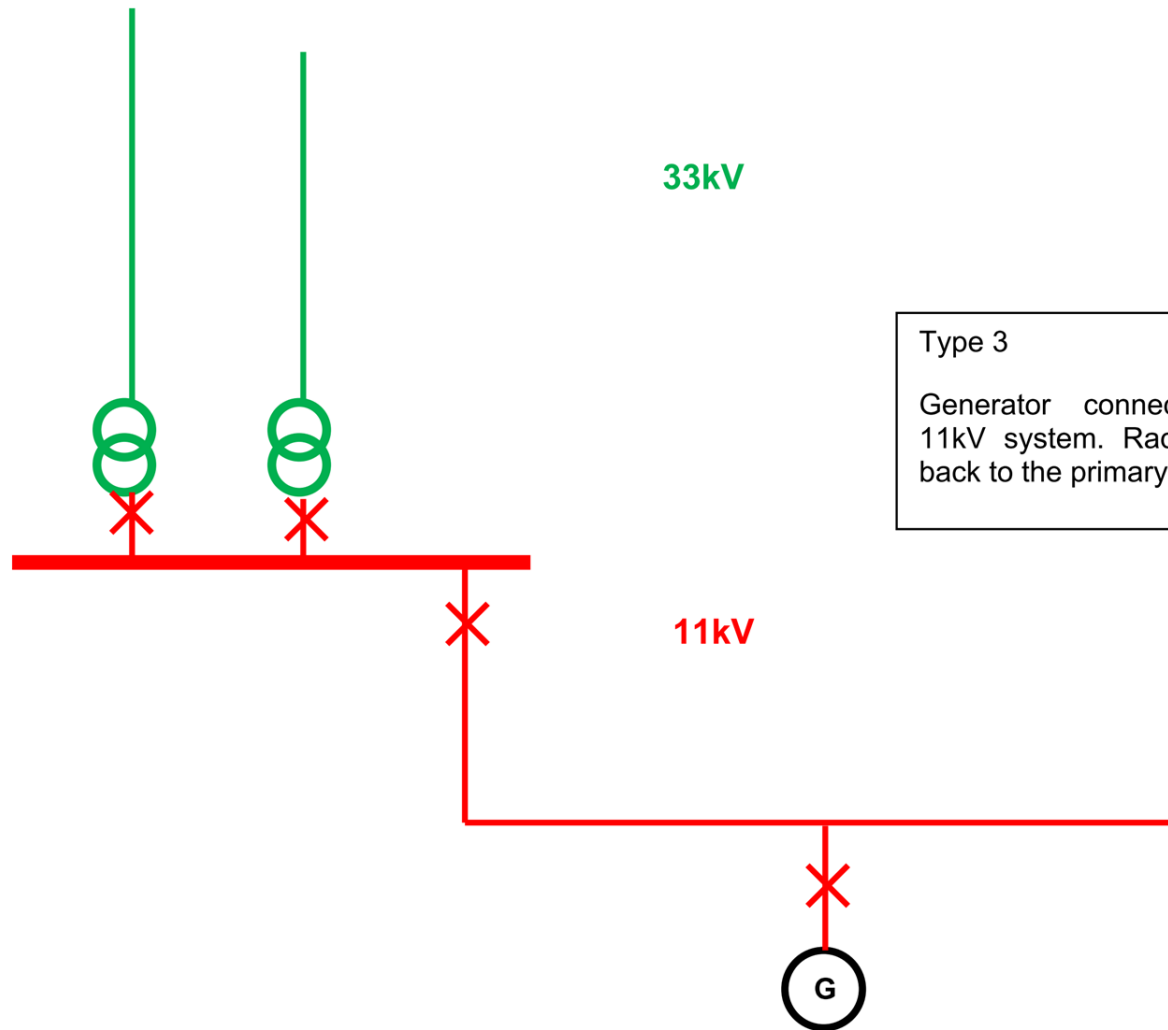
Generator connected at 33kV at  
a primary busbar

# Island formation options



Type 2  
Generator connected at 11kV at  
a primary busbar

# Island formation options



33kV

Type 3

Generator connected on the 11kV system. Radial connexion back to the primary

11kV

G

# Island formation options

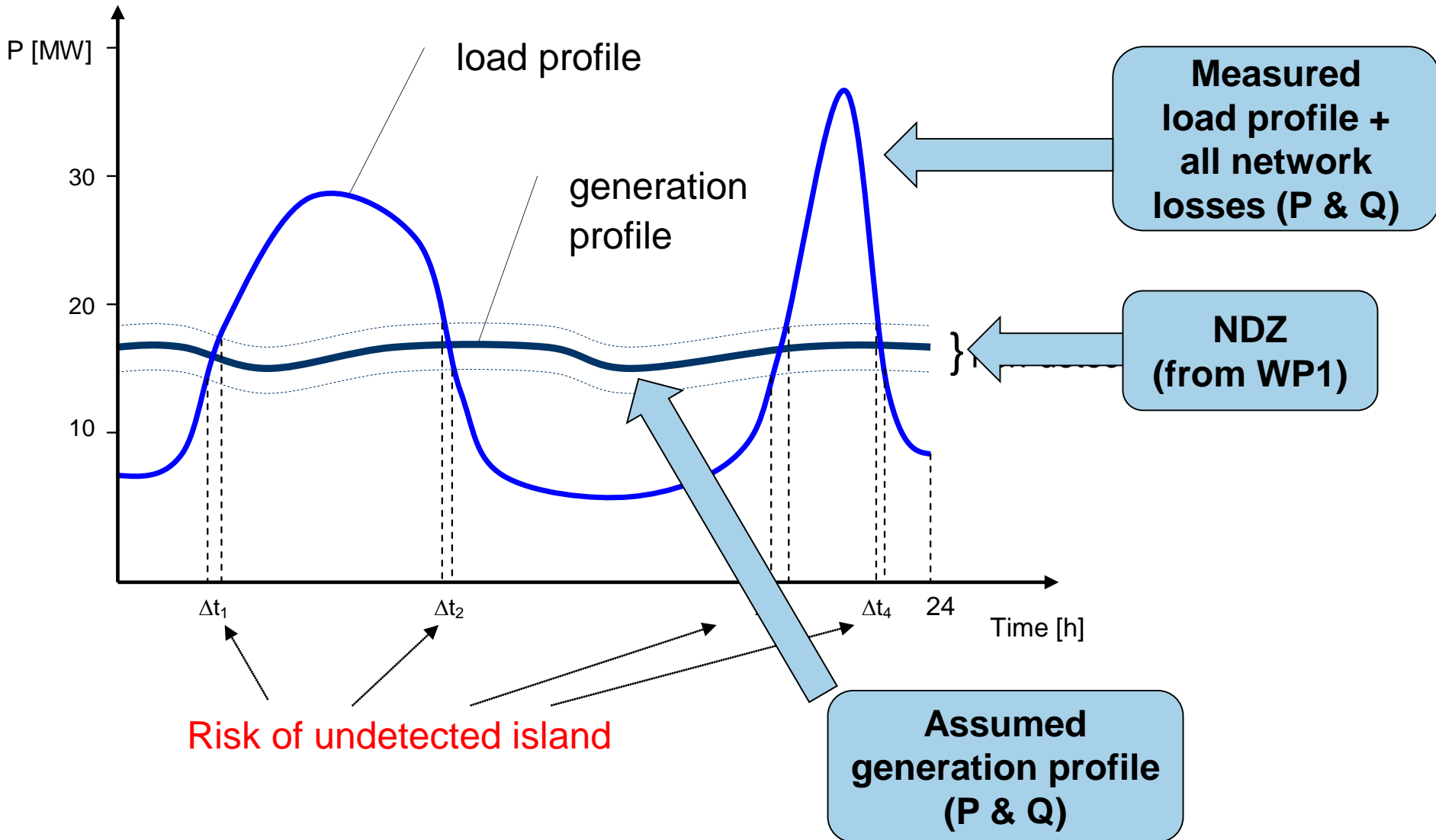


Type 4

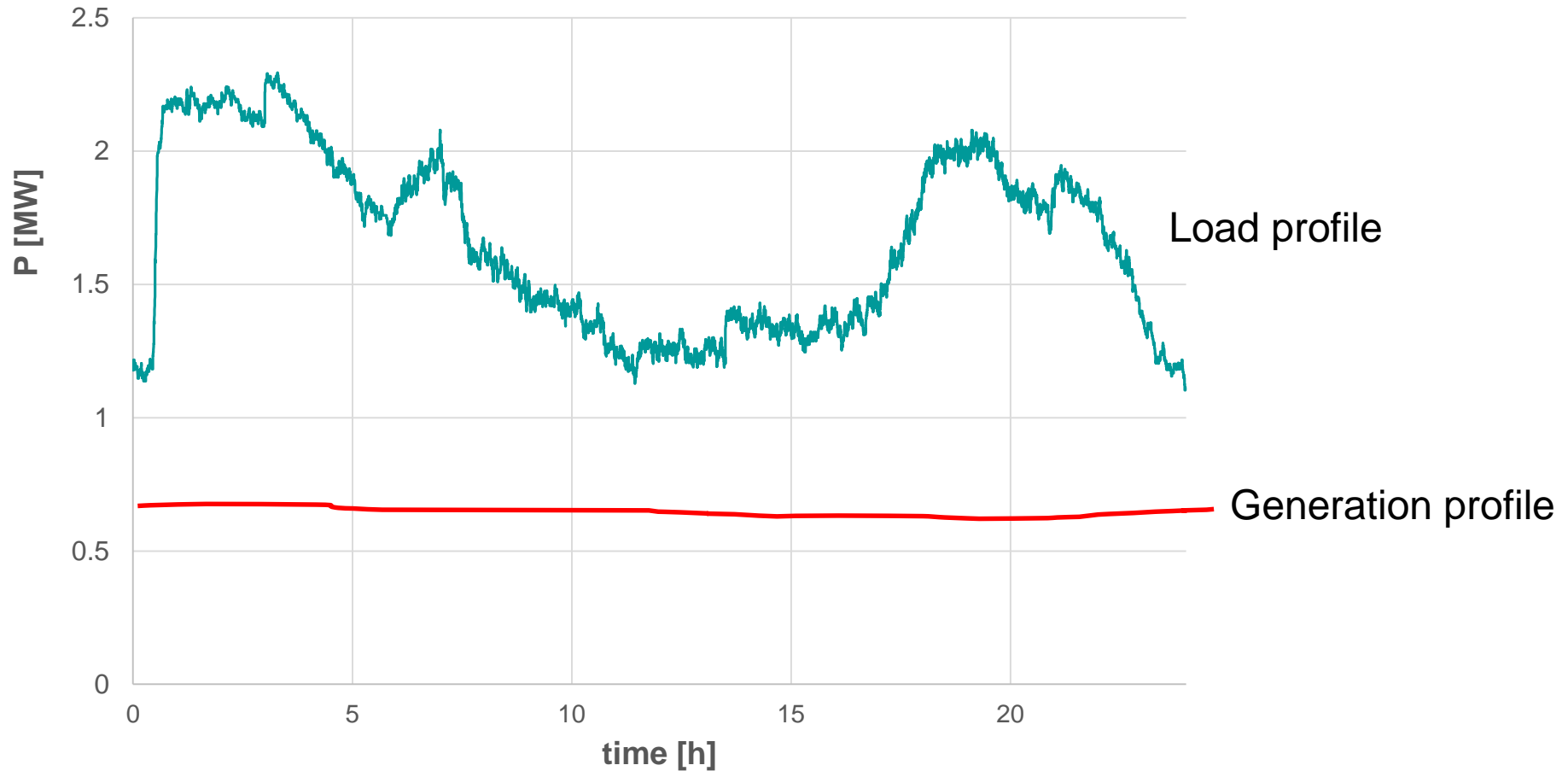
Teed to a passing 33kV circuit



# Probability of Load/Generation matching

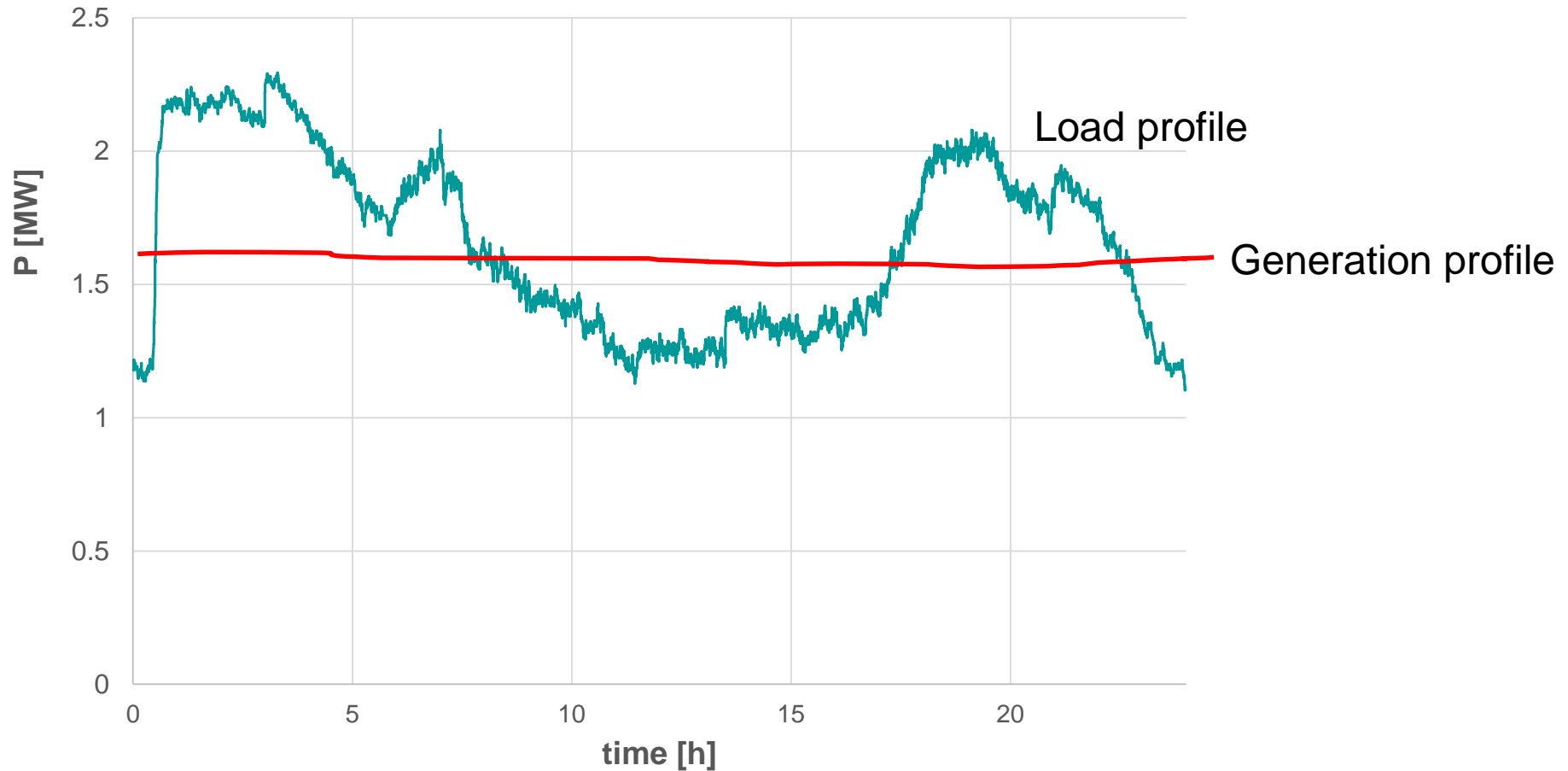


# Probability of Load/Generation matching



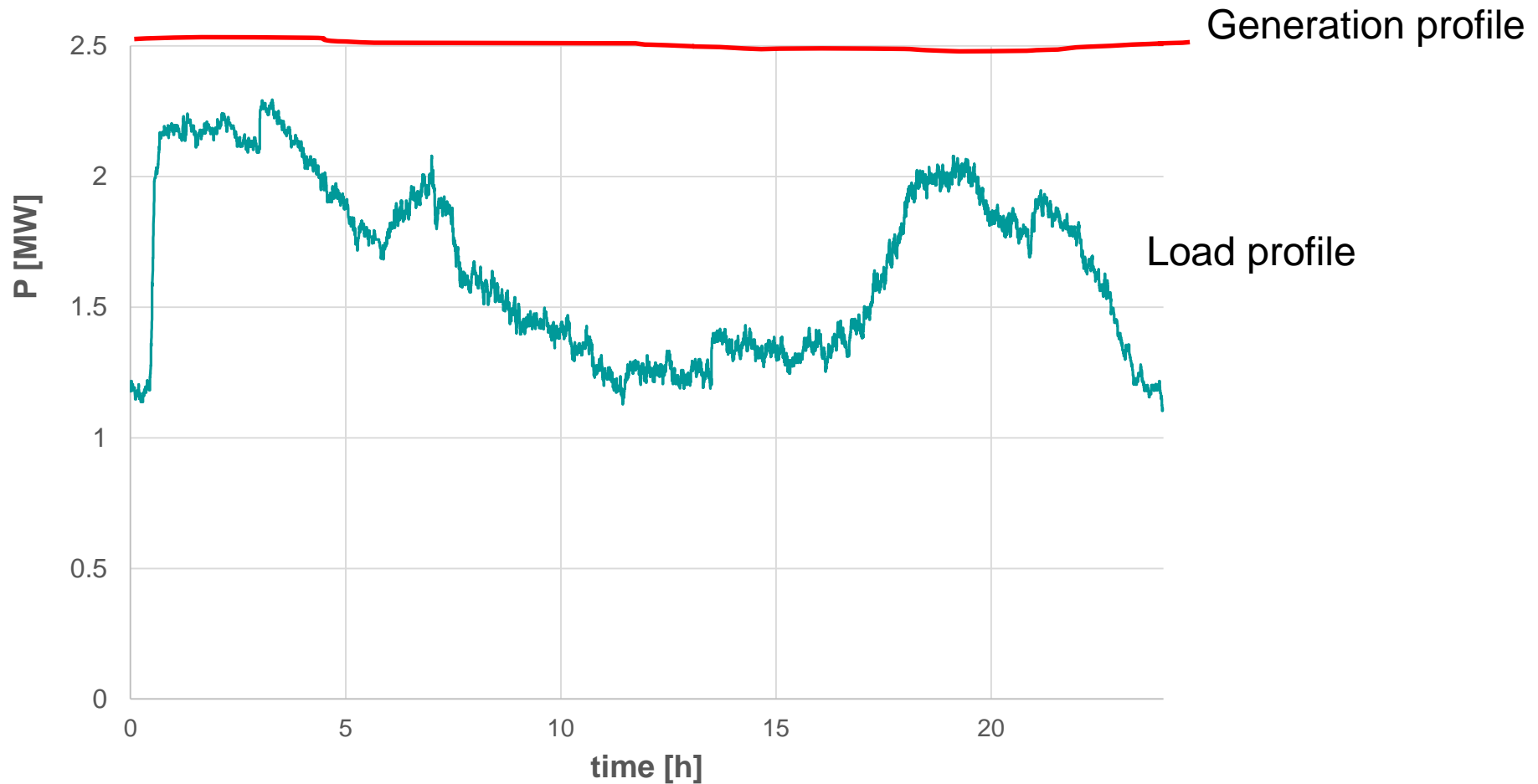
Low undetected island probability

# Probability of Load/Generation matching



Increased undetected island probability

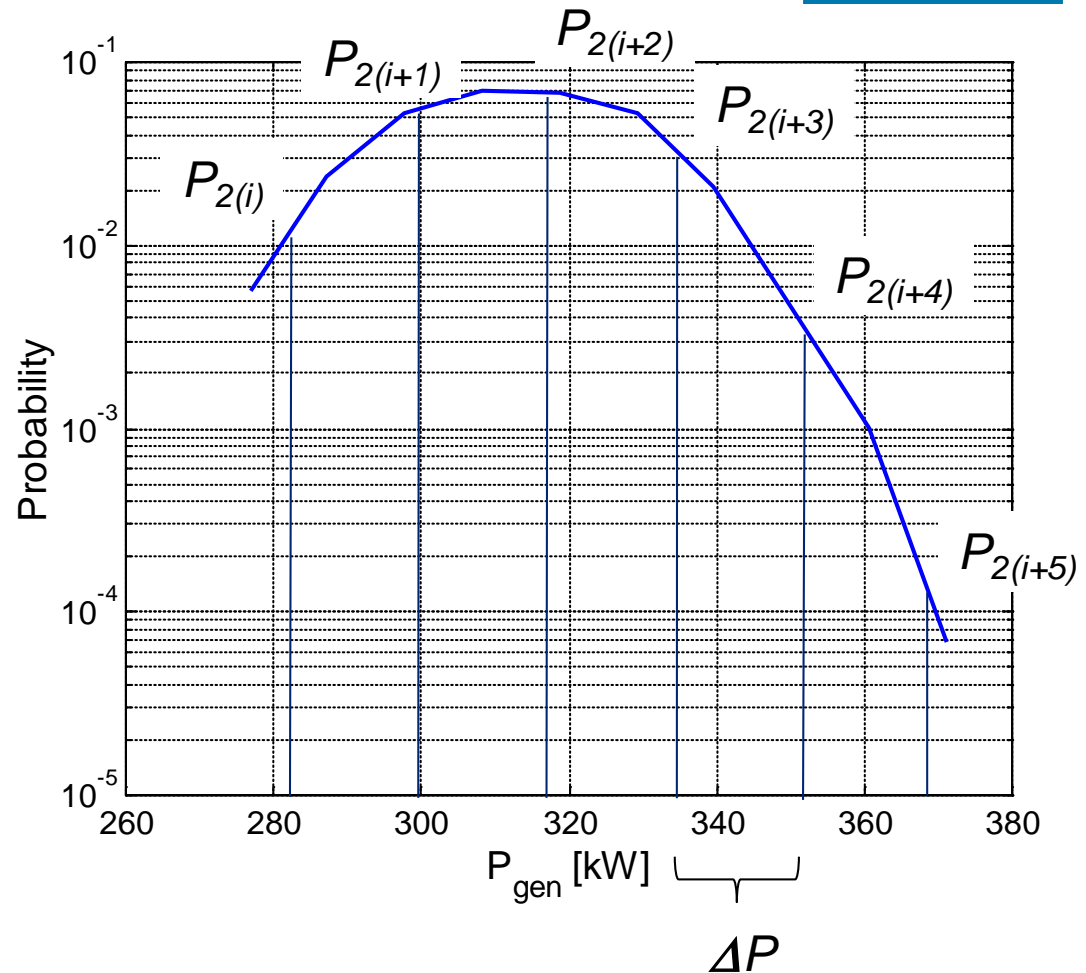
# Probability of Load/Generation matching



Low undetected island probability

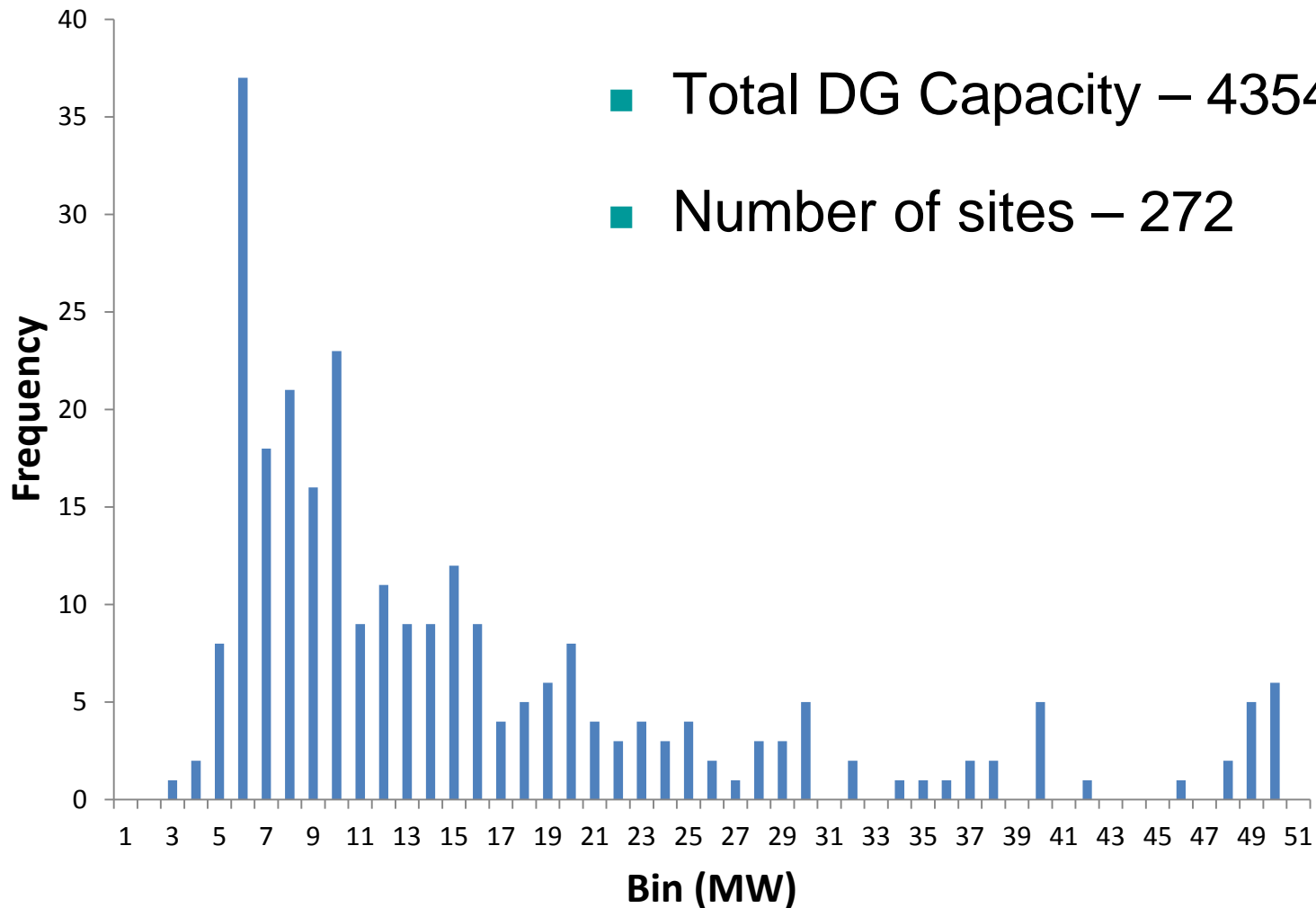
# Randomising generator size

- Marginal probability principle is used for calculating overall probability
- Generator sizes from 5MVA to 50MVA
- Using UK DG statistics to establish DG size distribution

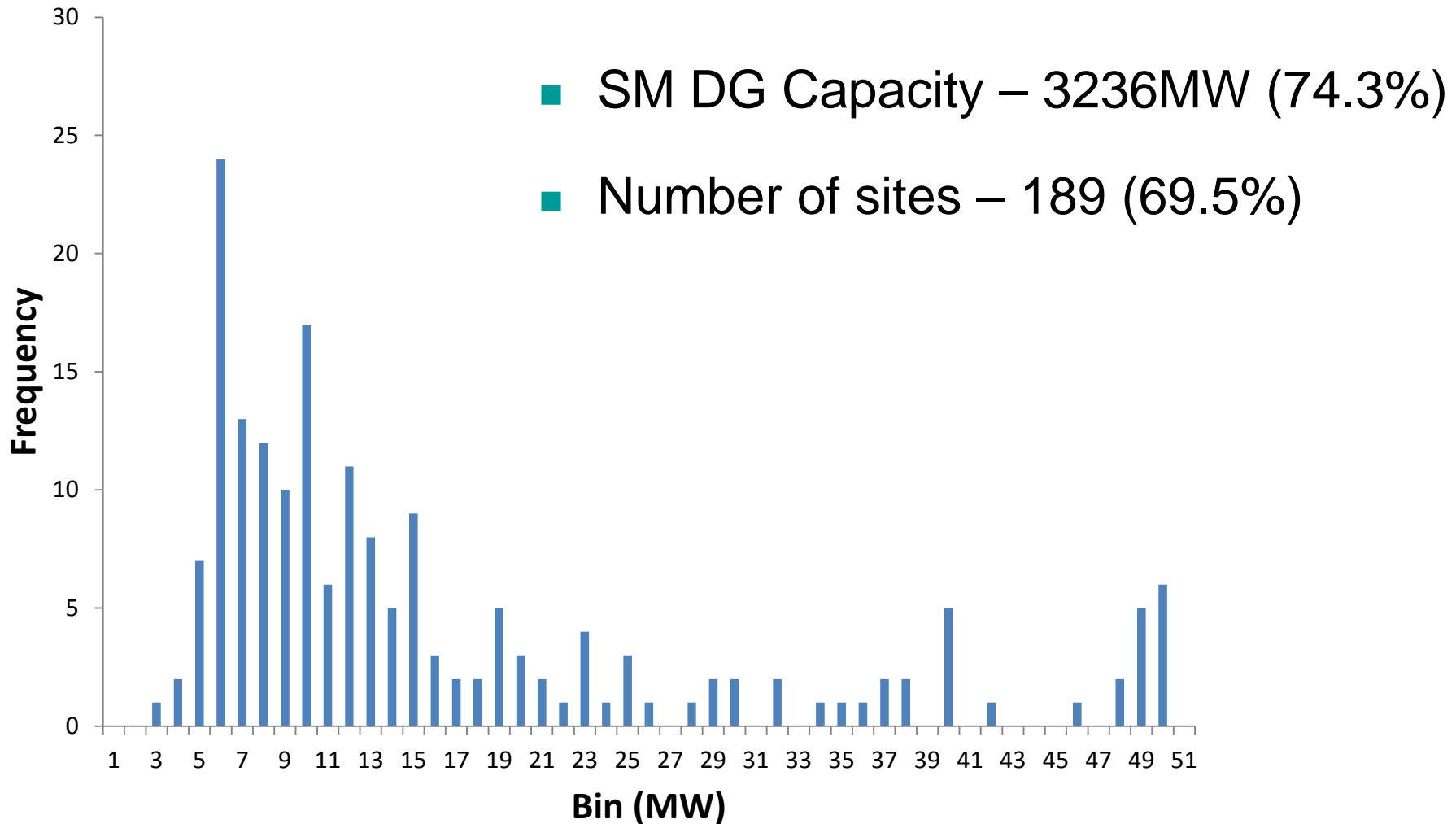


Non-detection zone probability at varying levels of generator output

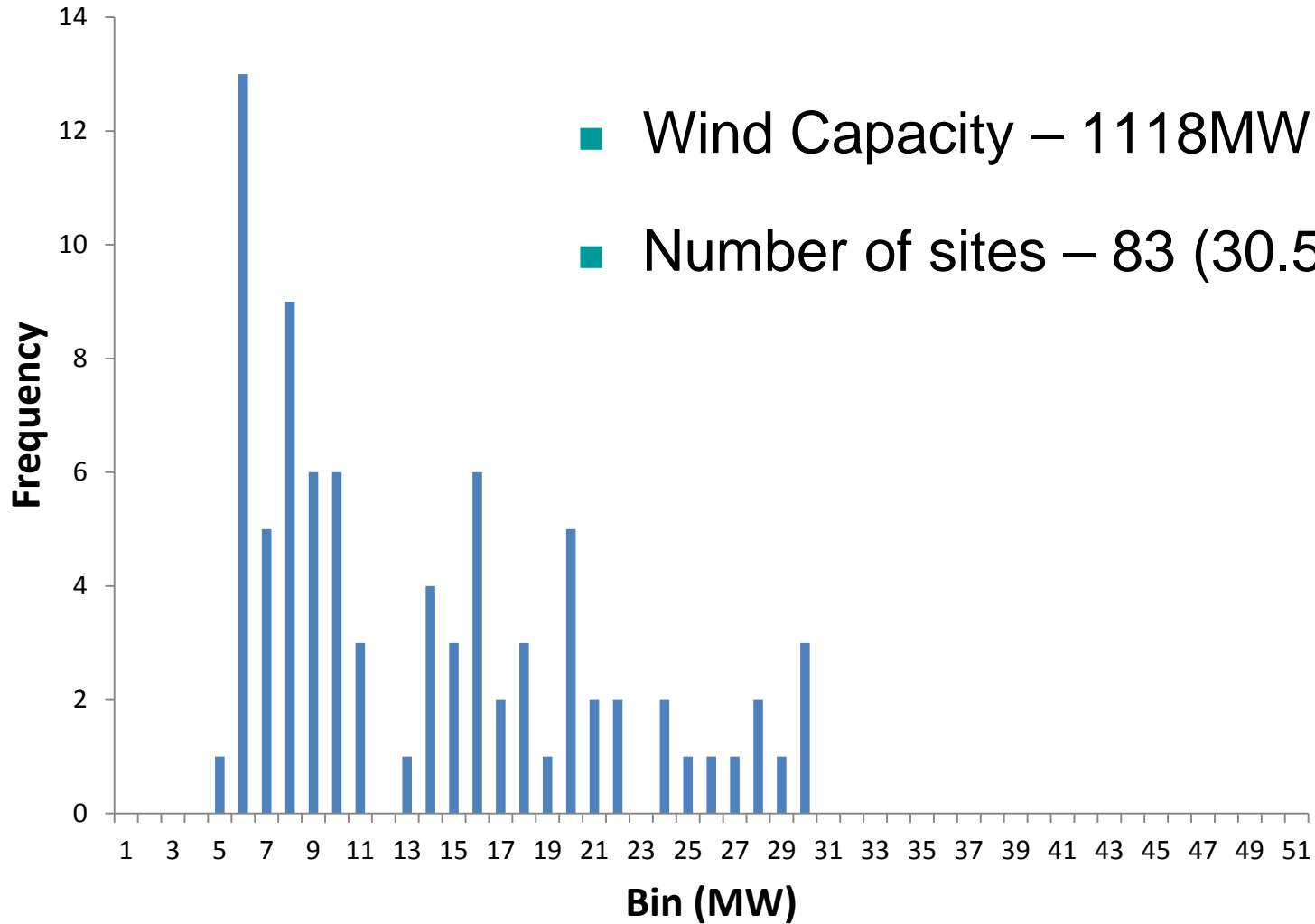
# DG Statistics (5MW-50MW)



# SM based DG (5MW-50MW)

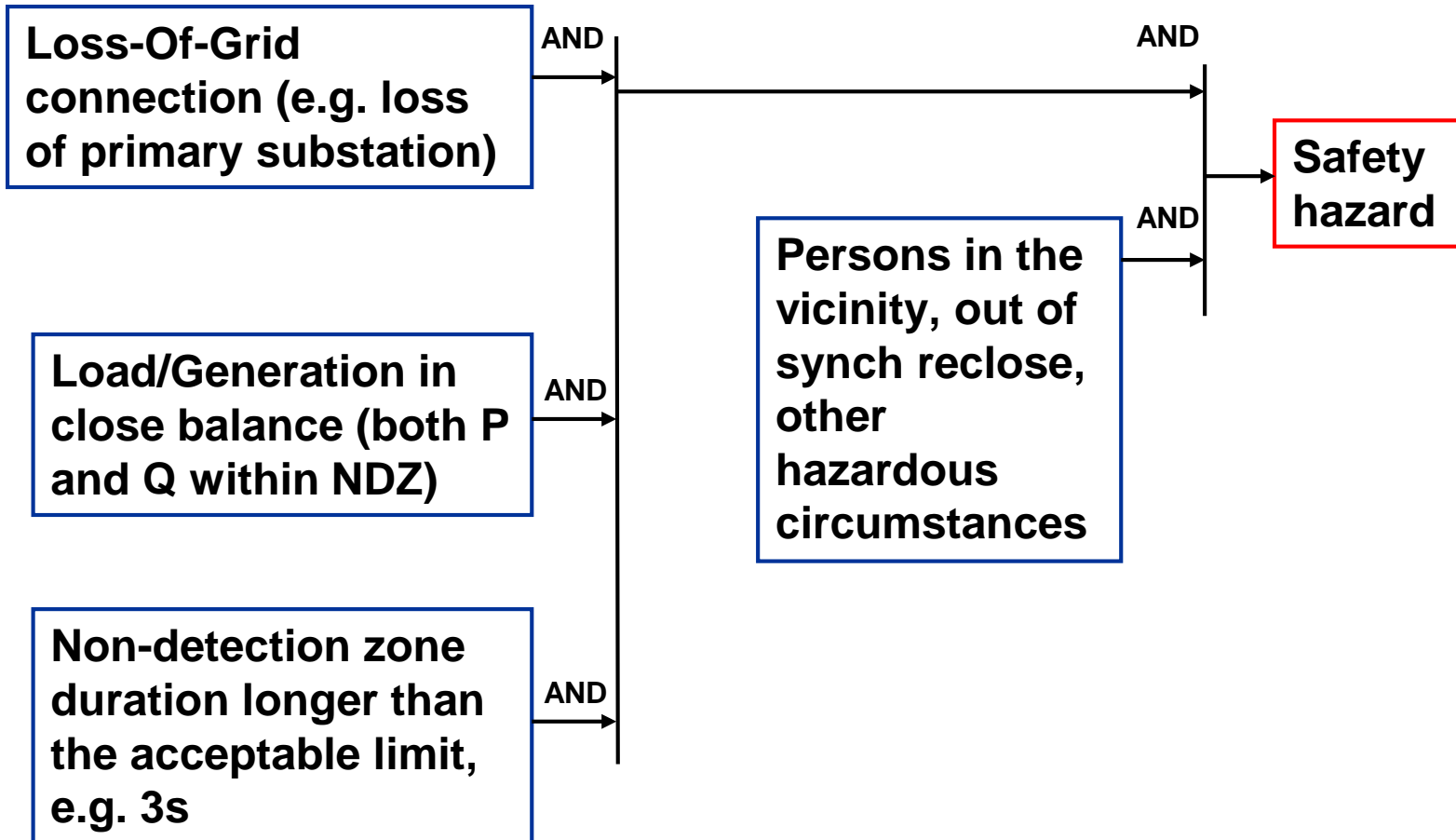


# Wind generation (5MW-50MW)





# LOM Safety Hazard Probability Tree



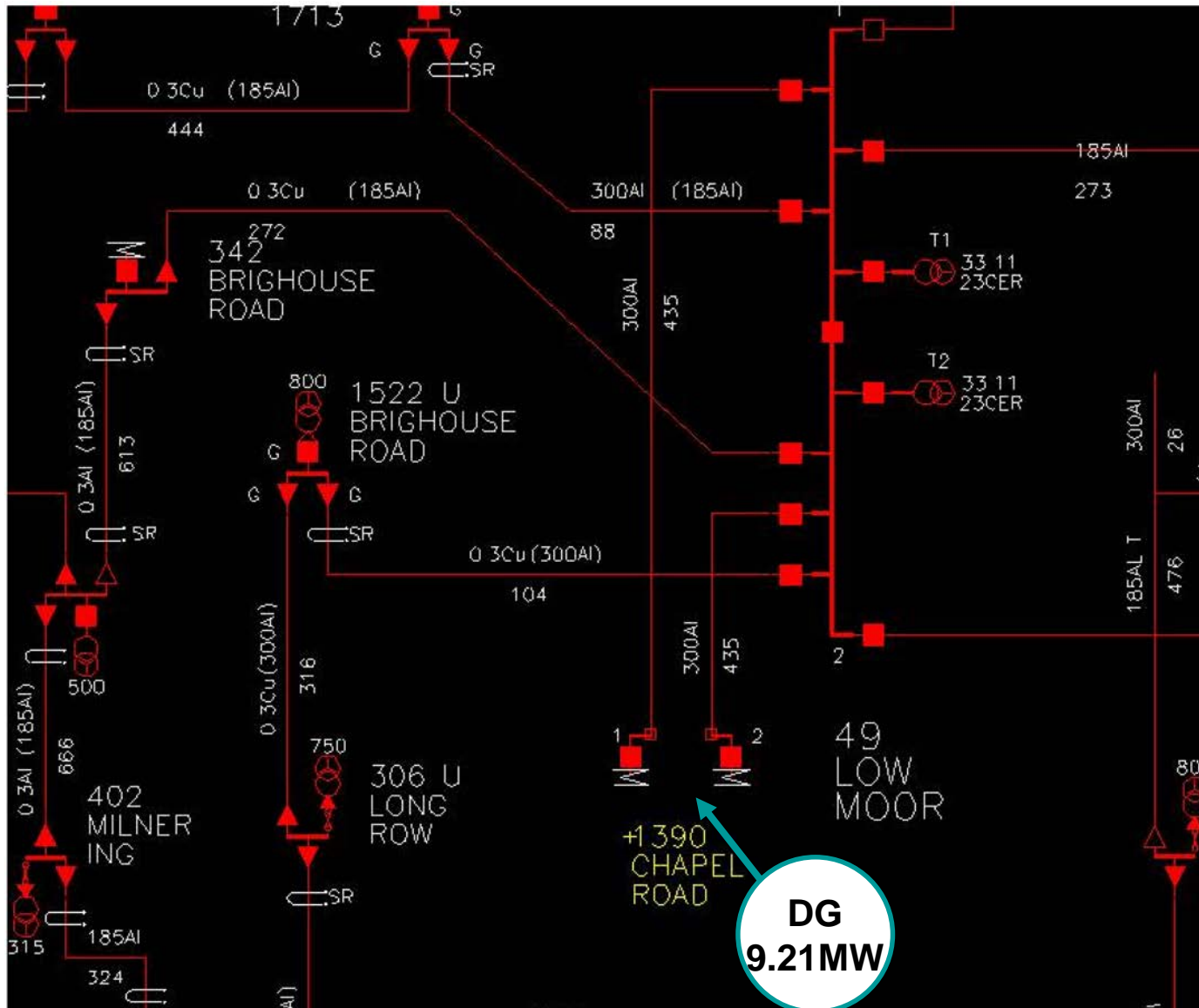
# Phase I – DNO data

# Requested data

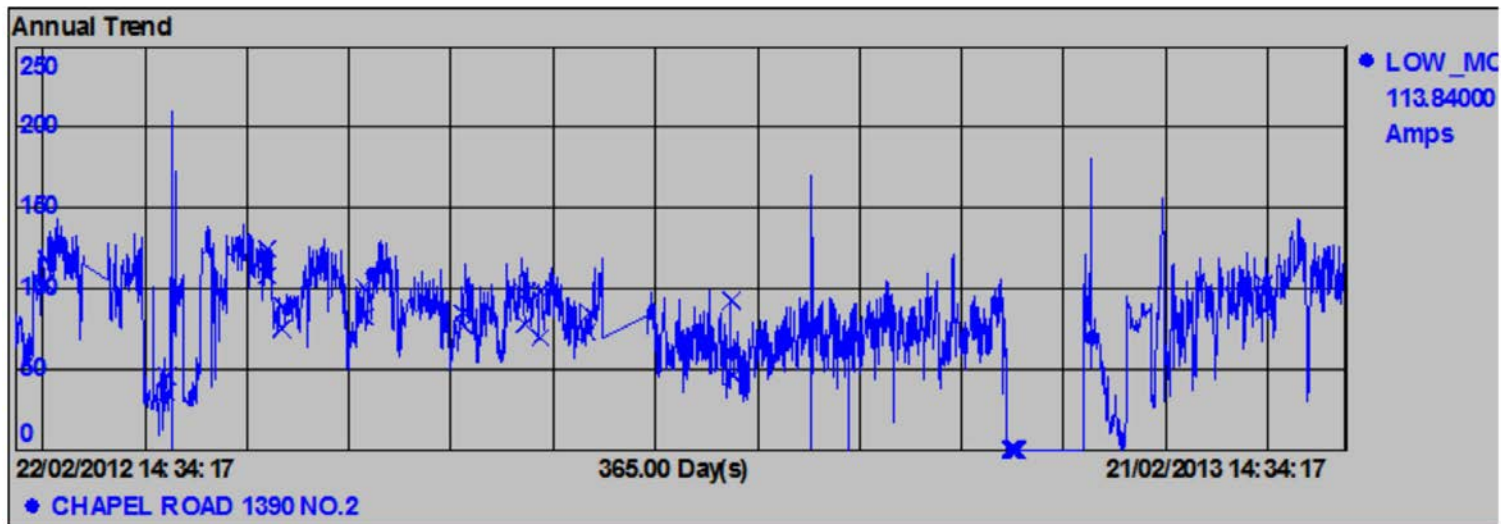
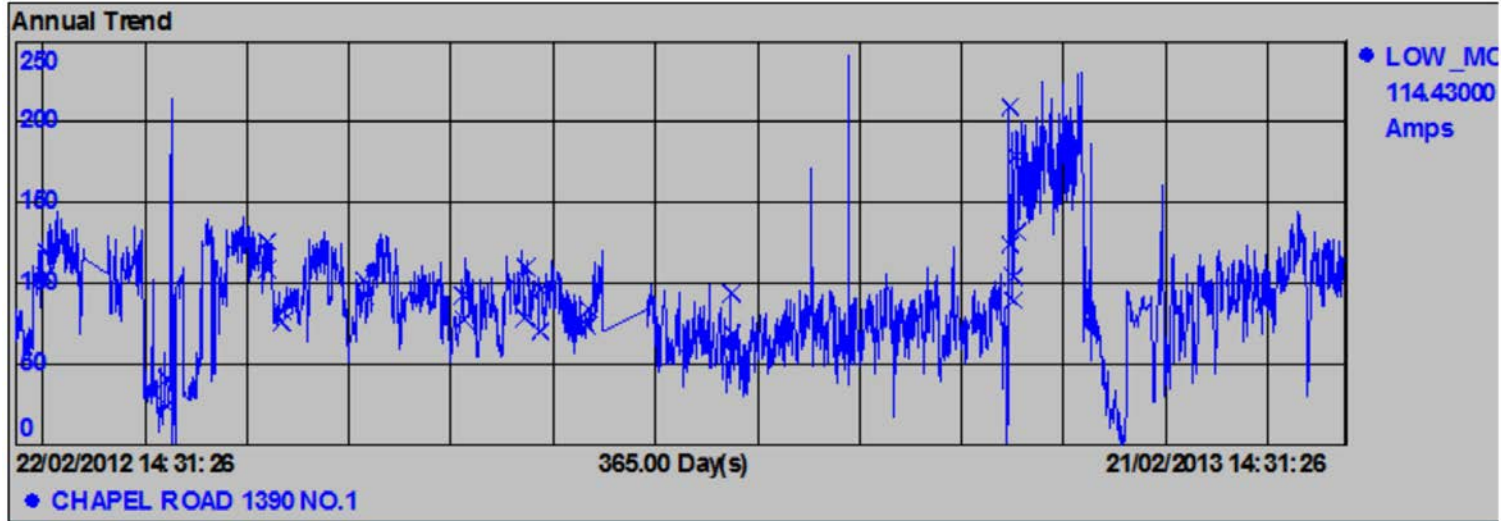


- Examples of load profiles (both P and Q) recorded at a primary substation over a period of minimum 1 day with sampling period of 5s or less. – *some examples received*
- Total number of DGs and amount of installed DG capacity in the range between 5MW and 50MW, as well as the envisaged DG numbers and capacity in 5 years' time. – *extracted from DCRP\_12\_02\_04*
- Typical DG connections for sizes between 5MW and 50MW (choose from the four types as shown below) – *continues*
- Typical (or average or min/max) size of network fed from a primary substation (i.e. potentially islanded) in terms of overall length of lines (cables and OHLs) at 33kV and 11kV, and number of transformers (33/11kV). – *not crucial*
- Current LOM practice for generators between 5MW and 50MW (ROCOF, VS or Intertripping) and estimated amount of DG with ROCOF protection. – *continues*
- Total number of substations and frequency of occurrence of losing a primary substation, i.e. frequency of potential islanding conditions. – *continues*

# Western Power Grid Data

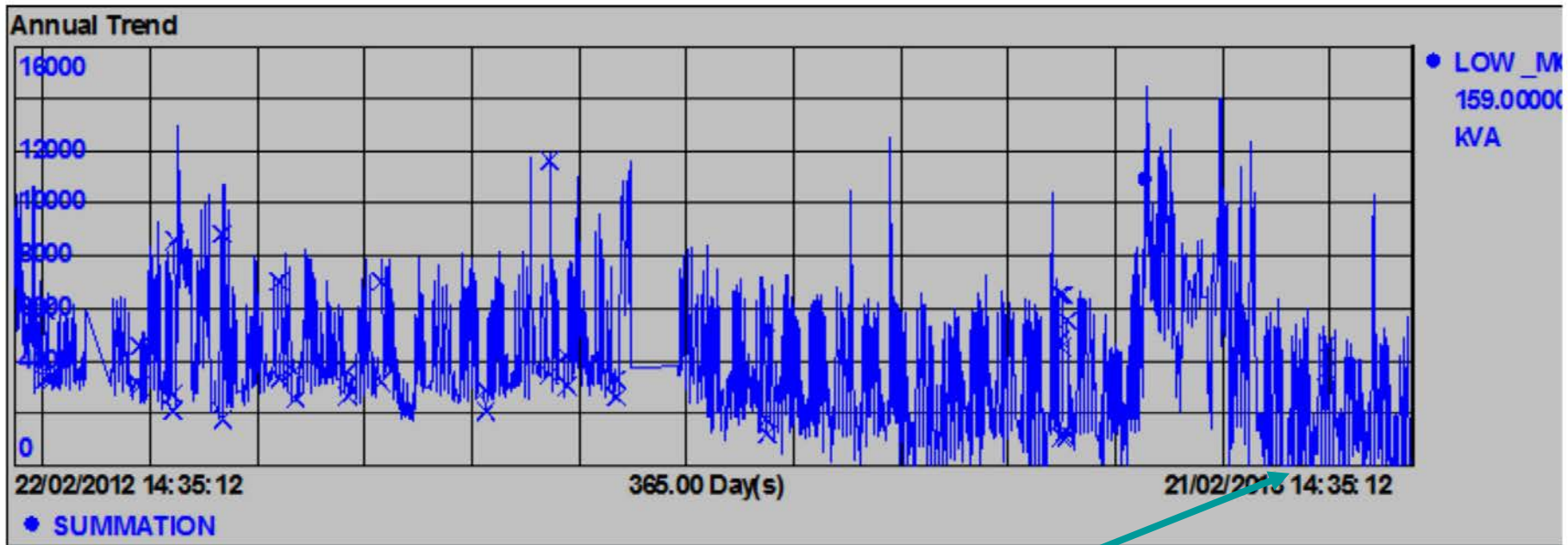


# Western Power Grid Data



# Western Power Grid Data

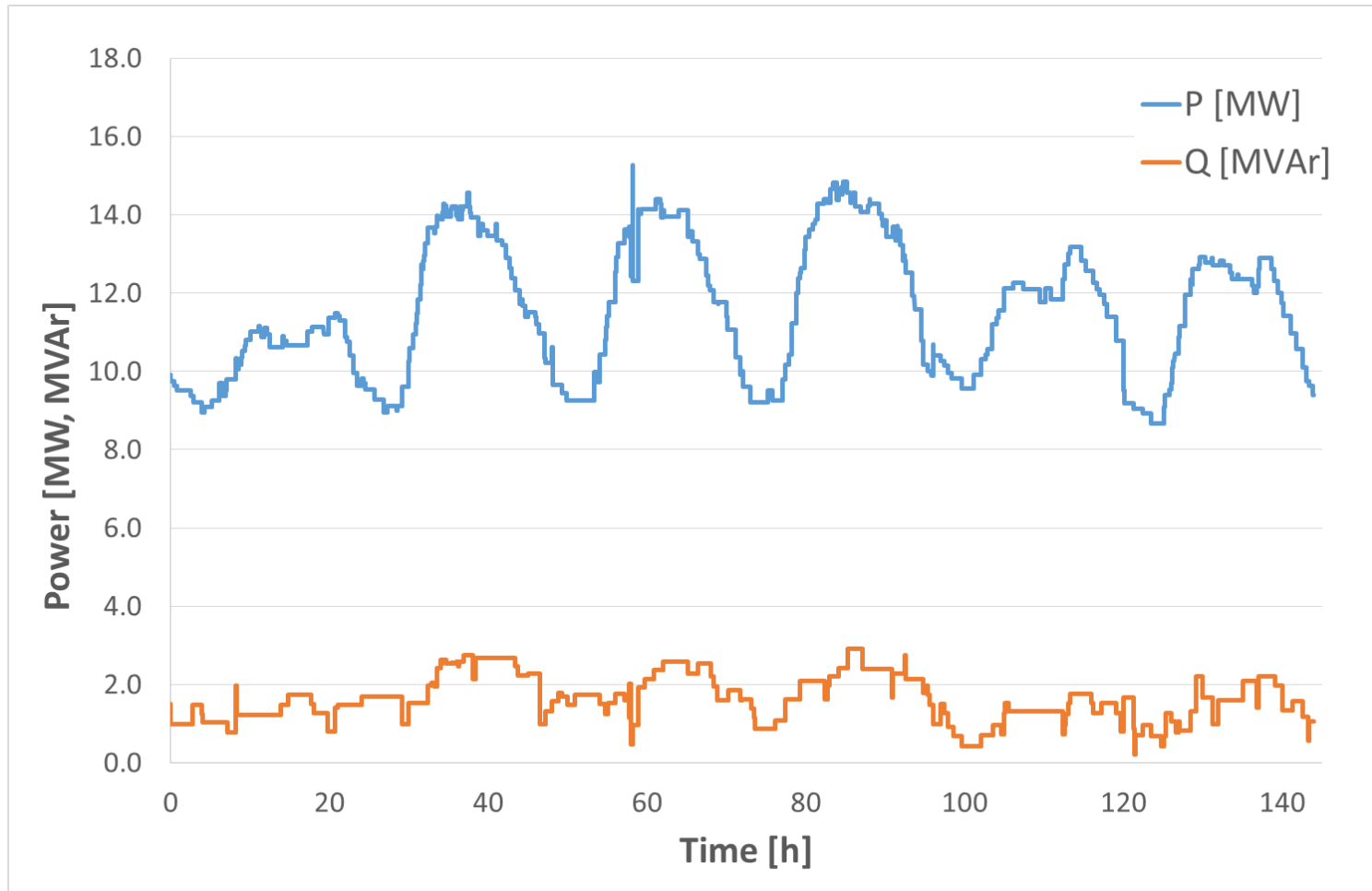
- 1 year data
- Sampling period 0.5h
- Current only



Potential export (?)

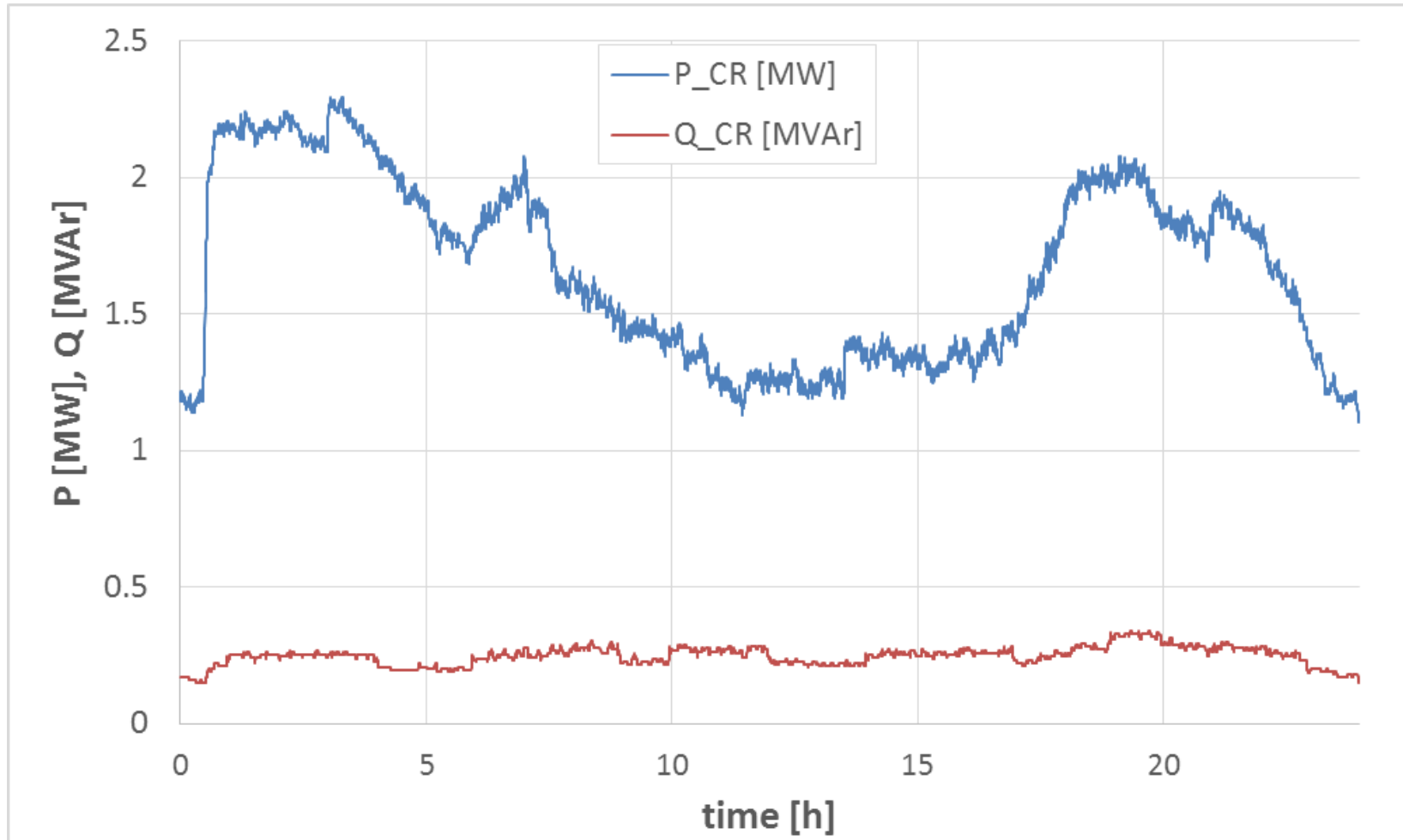
# SSE Load Data

- Mixed residential industrial load – 6 days over 1 year
- Sampling period 5s



# SPM Load Data

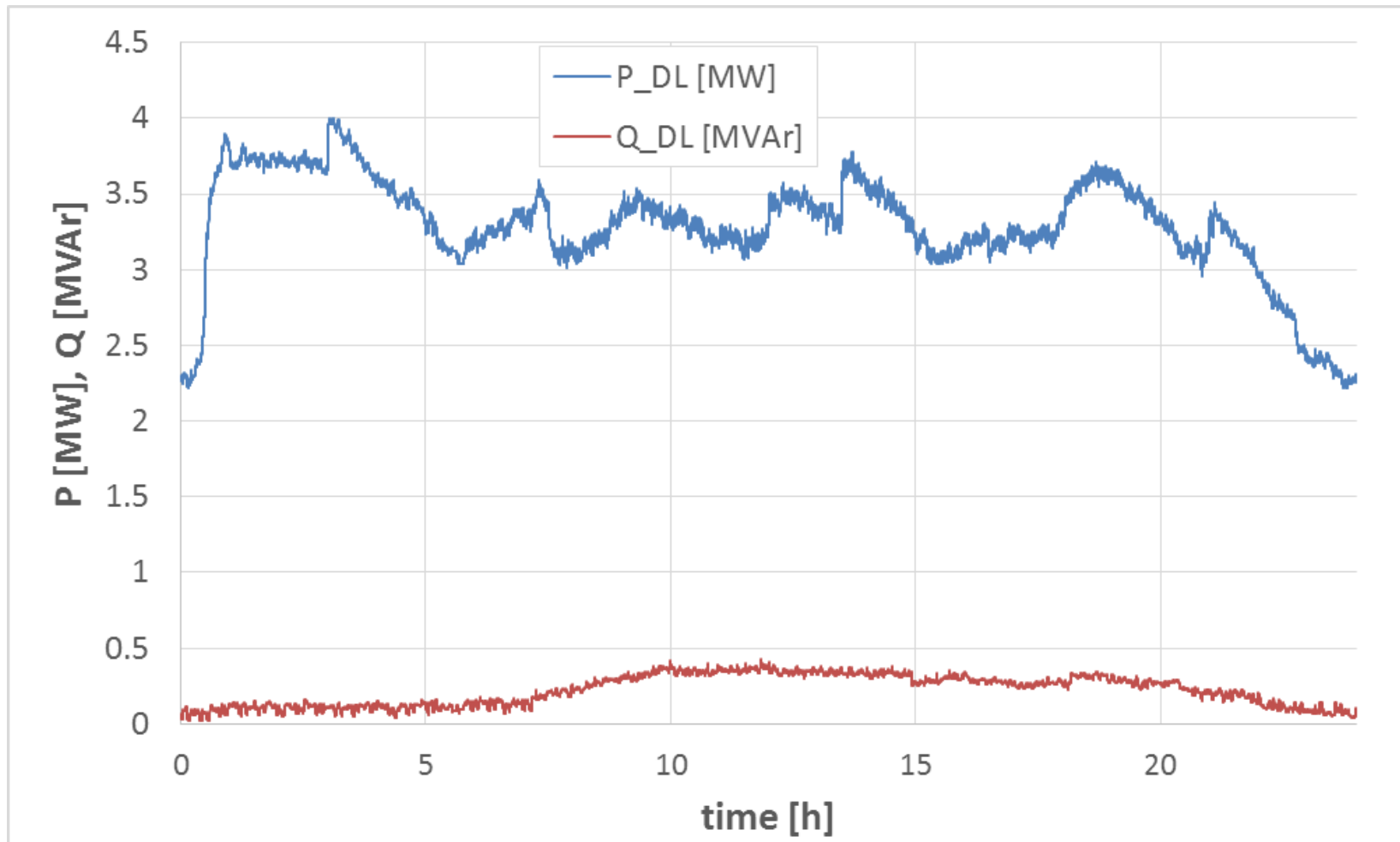
- 3 rural primes – 1 day
- Sampling period 5s





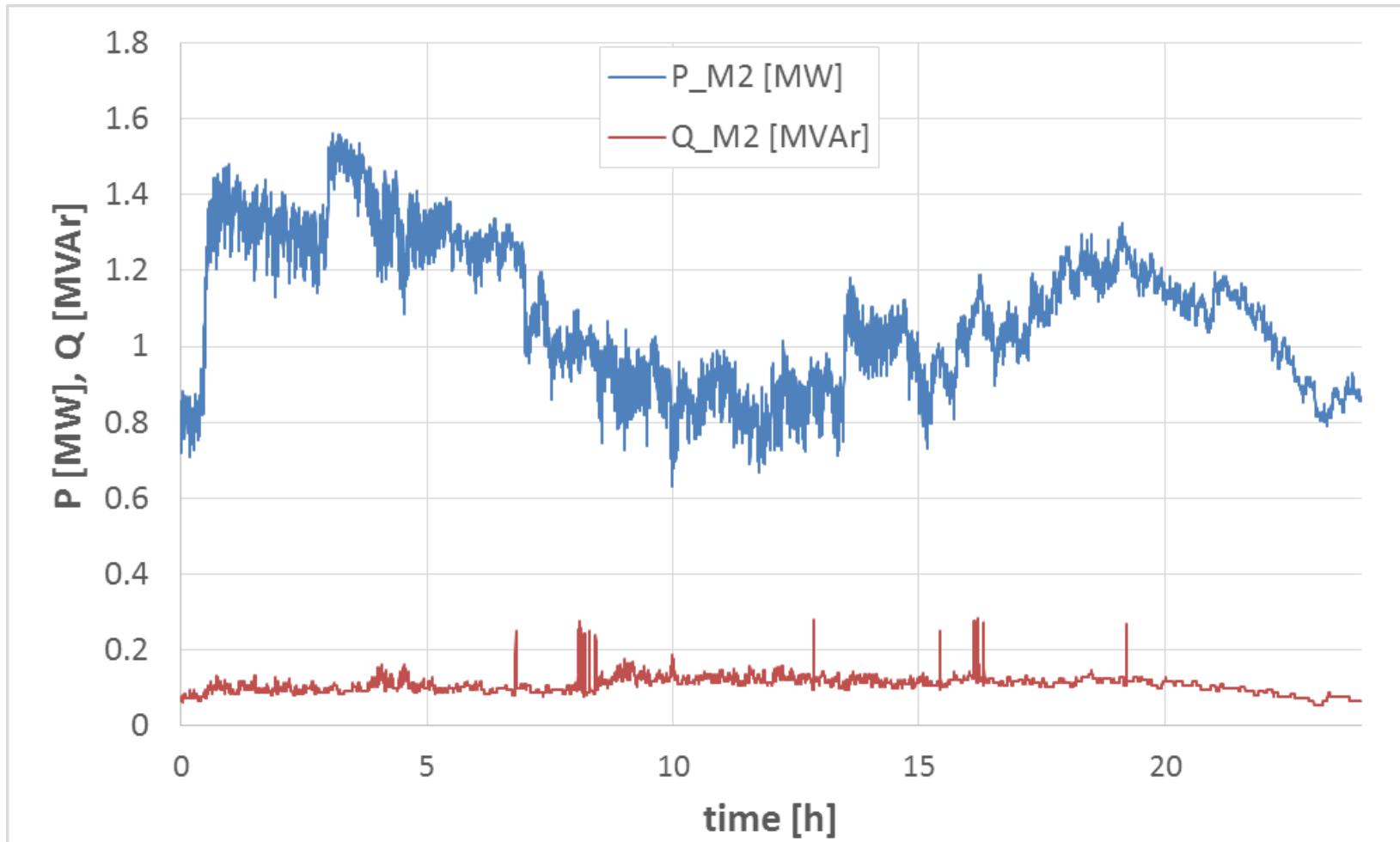
# SPM Load Data

- 3 rural primes – 1 day
- Sampling period 5s

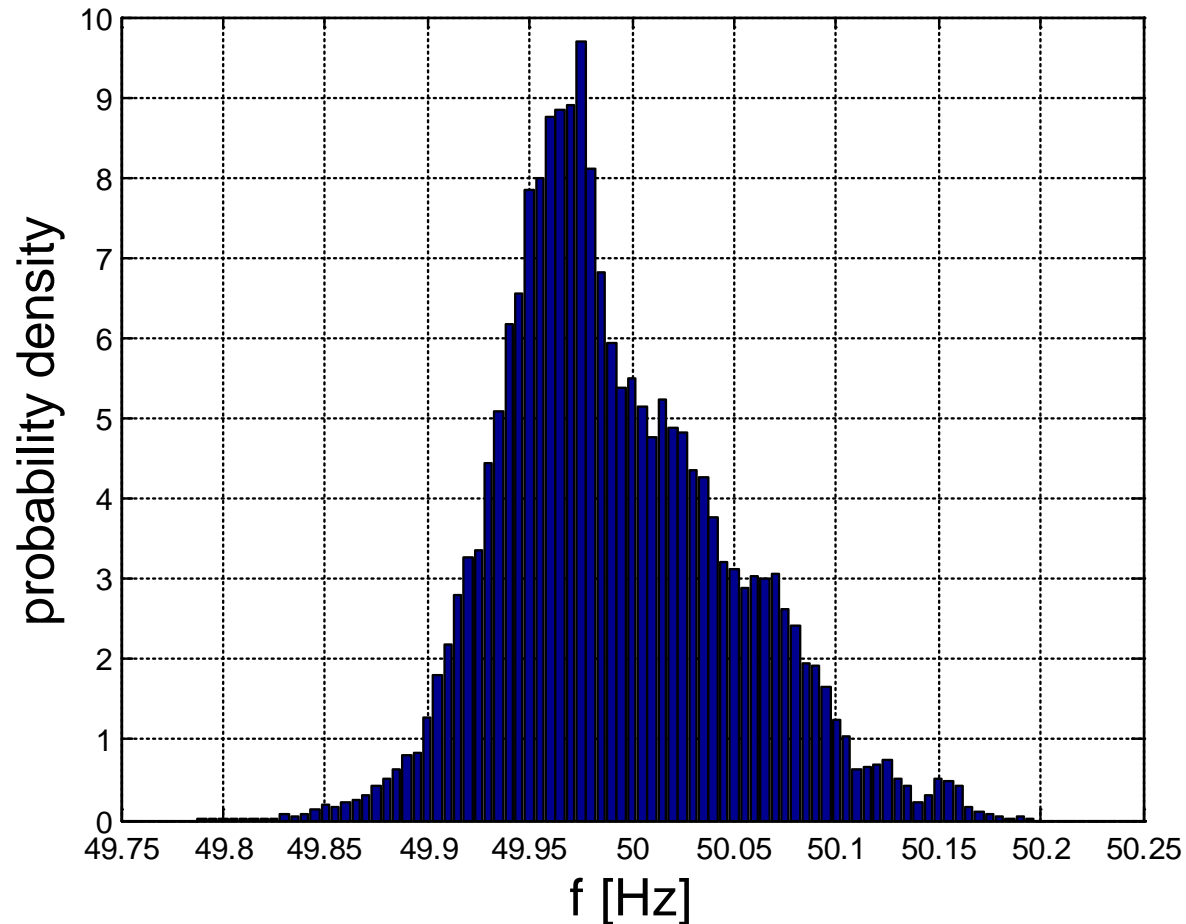


# SPM Load Data

- 3 rural primes – 1 day
- Sampling period 5s

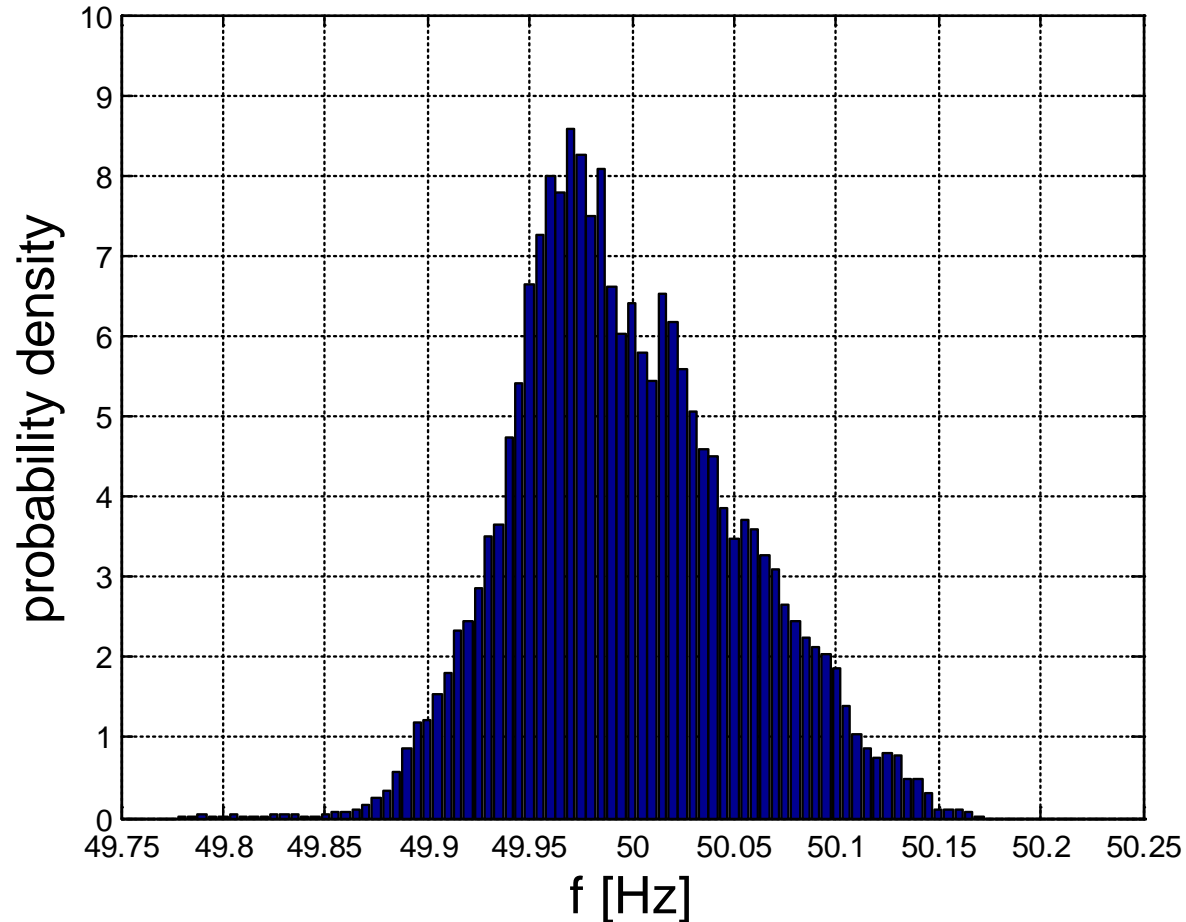


# System frequency



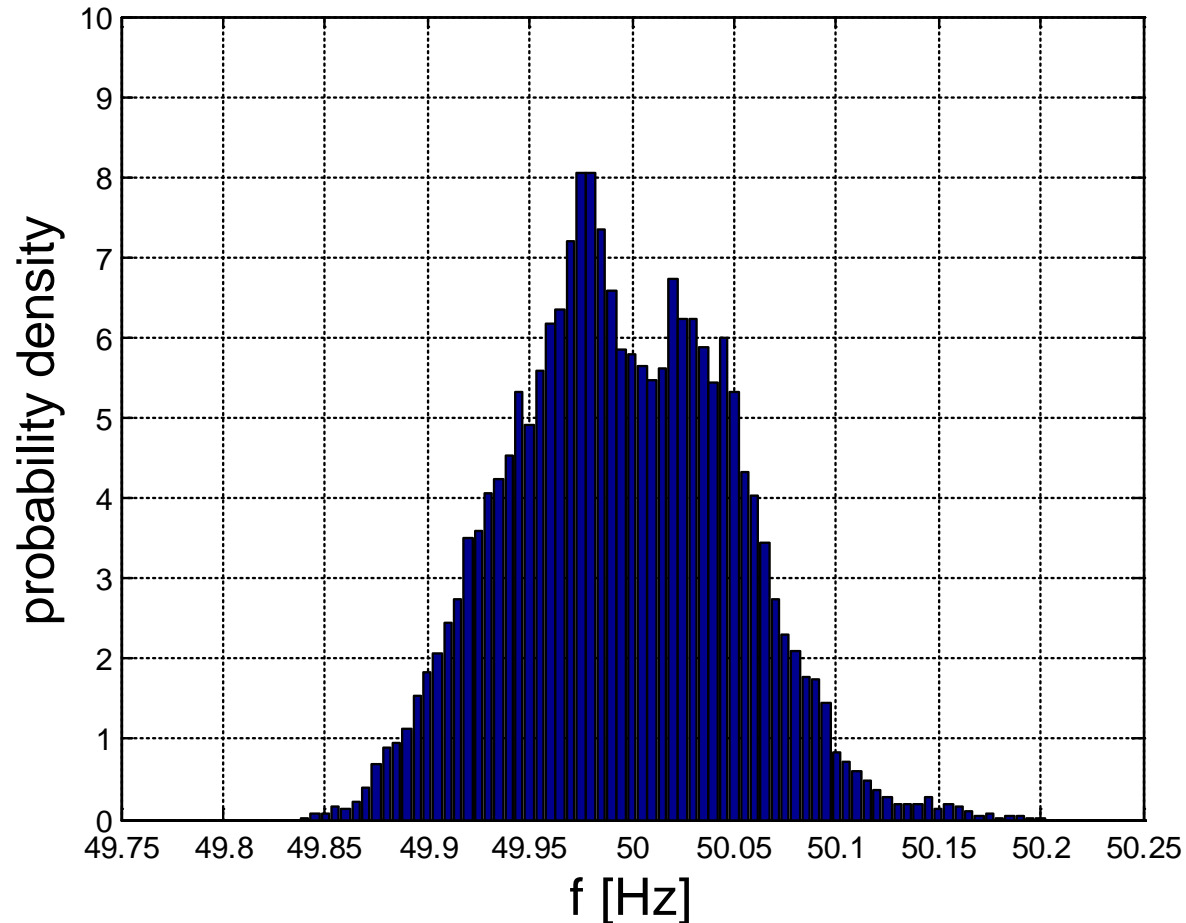
- 12 July 2012 - Thursday
- $f_{mean} = 49.9941$  Hz

# System frequency



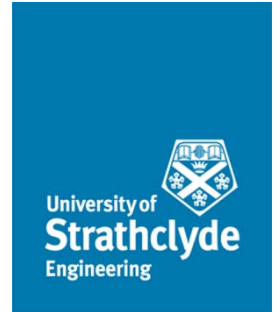
- 2 February 2013 - Saturday
- $f_{mean} = 50.0001$  Hz

# System frequency



- 14 March 2013 - Thursday
- $f_{mean} = 49.9970$  Hz

# Questions



- Load model (fixed impedance or fixed power)?
- Generation profile (loading at 90% rating and  $pf=0.98$  leading)?
- Generator control regime (P/pf, P/V)?
- Possible island formation scenarios?

# Progress to date



- Samples of load profiles and DG statistics have been obtained
- RTDS modelling has been commenced; base model has been setup
- UK frequency analysis has been undertaken to assess the effectiveness of the proposed frequency dead band.
- Phase I completion by end of May.
- Phase II – wind and PV generation stability assessment

**Thank you!**