Risk Assessment of Loss of Mains Protection

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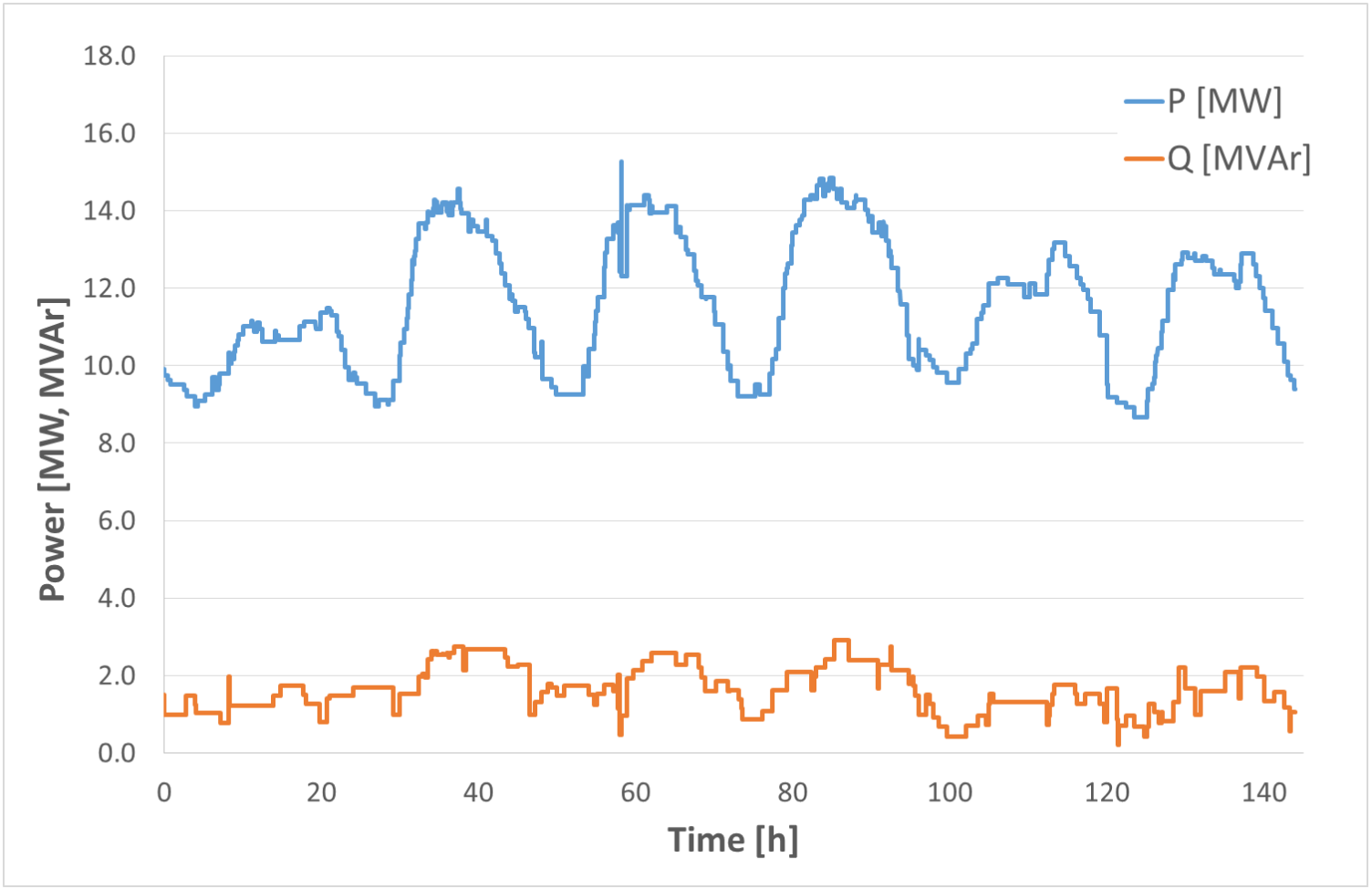
Outline

- DNO data (including questions)
- Progress to date
  - WP1: Laboratory testing of NDZ assessment
  - WP2: Initial risk calculations

DNO Data

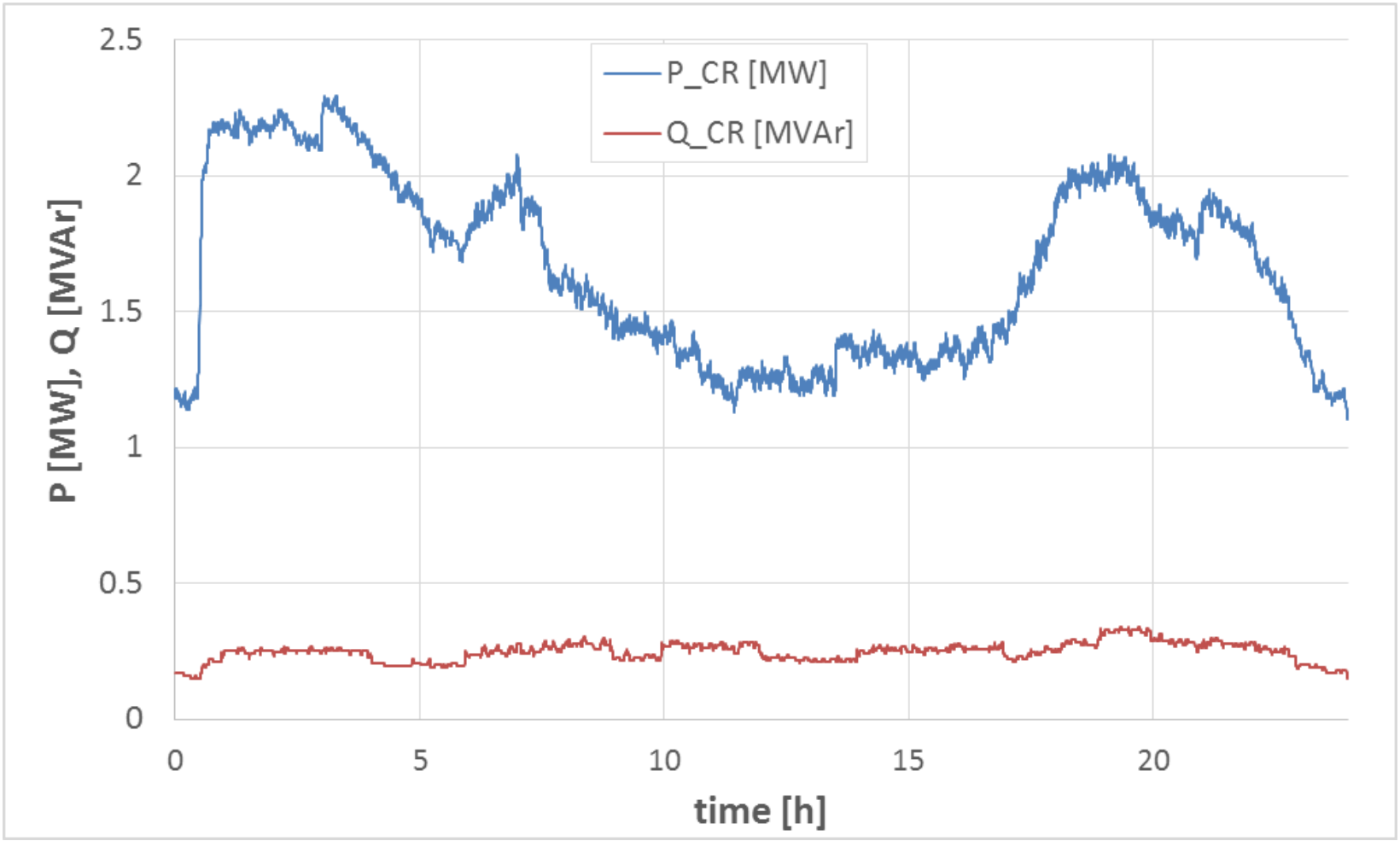
SSE Load Data – Load Case 1

- Mixed residential industrial load – 6 days over 1 year
- Sampling period 5s – resampled to 1s with linear interpolation



SPM Load Data

- 3 rural primes – 1 day
- Sampling period 5s – resampled to 1s with linear interpolation



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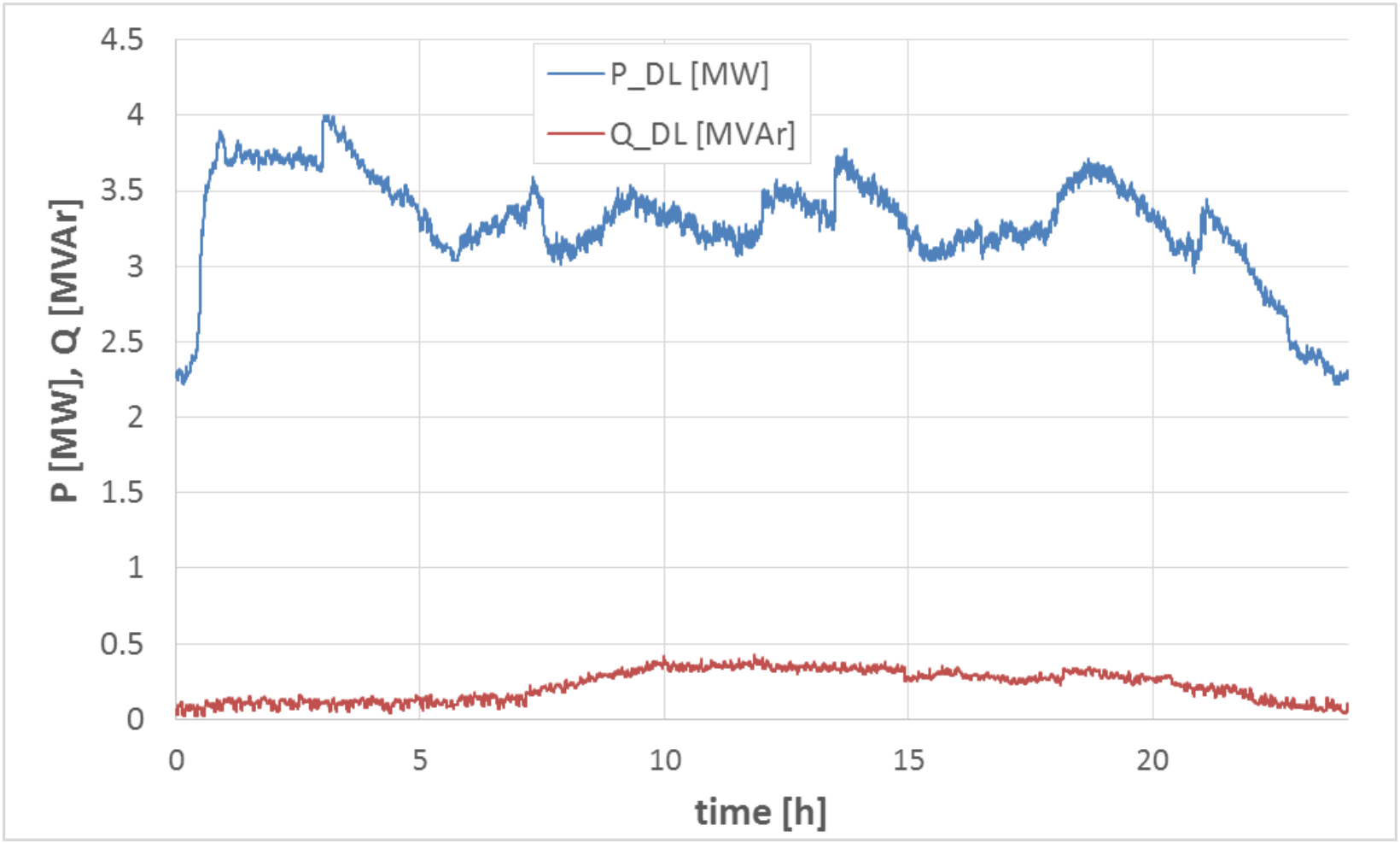

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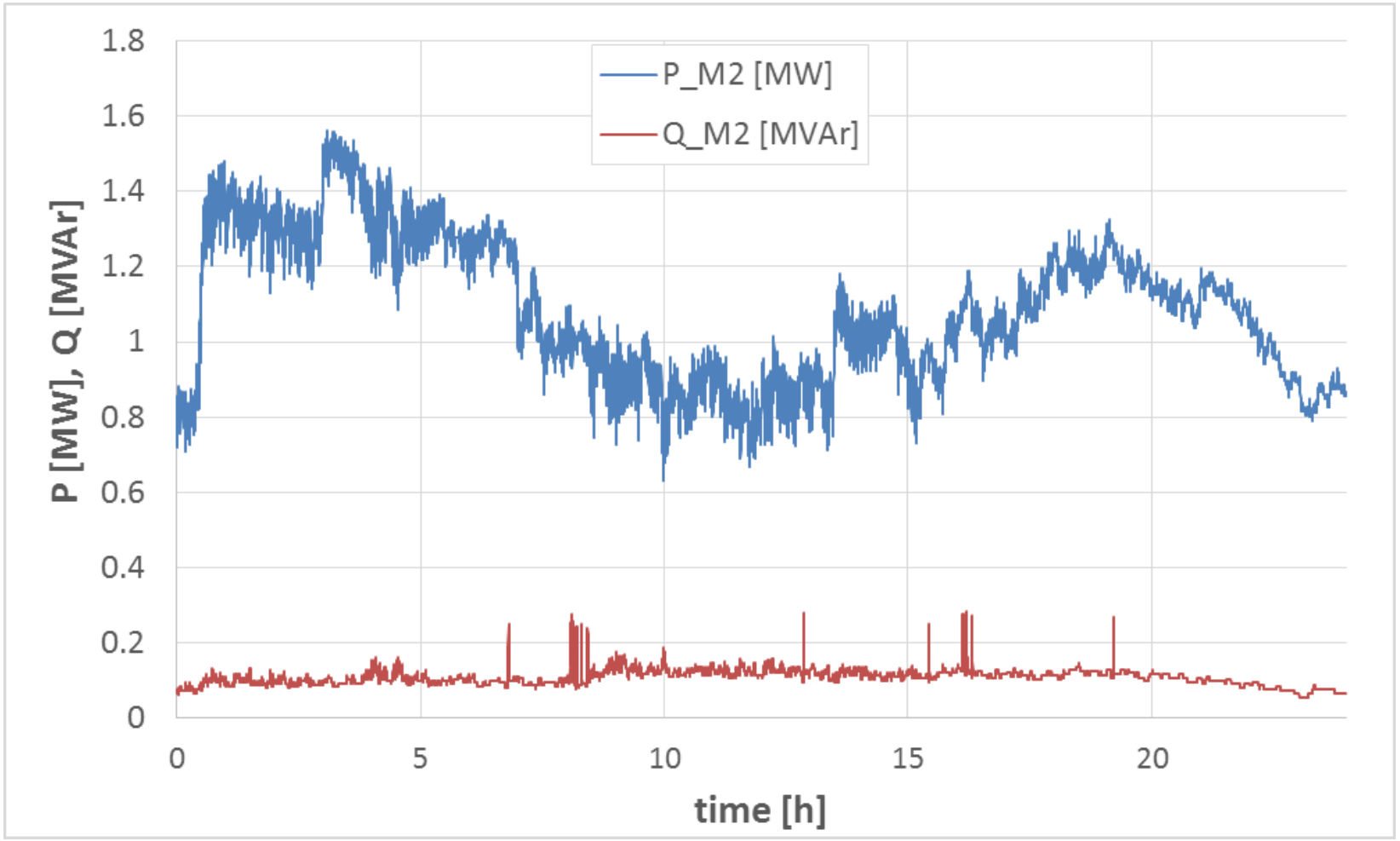

SPM Load Data

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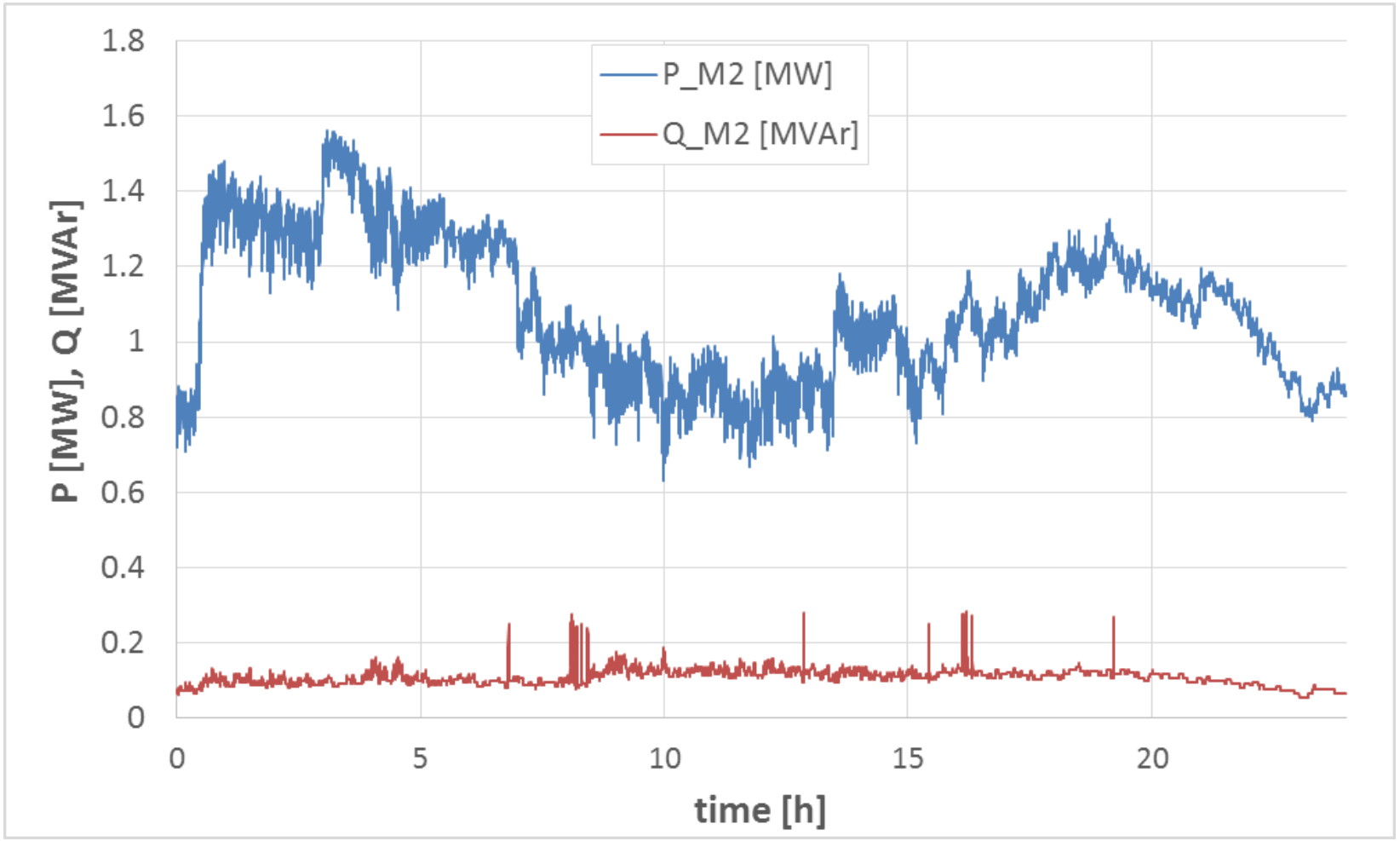
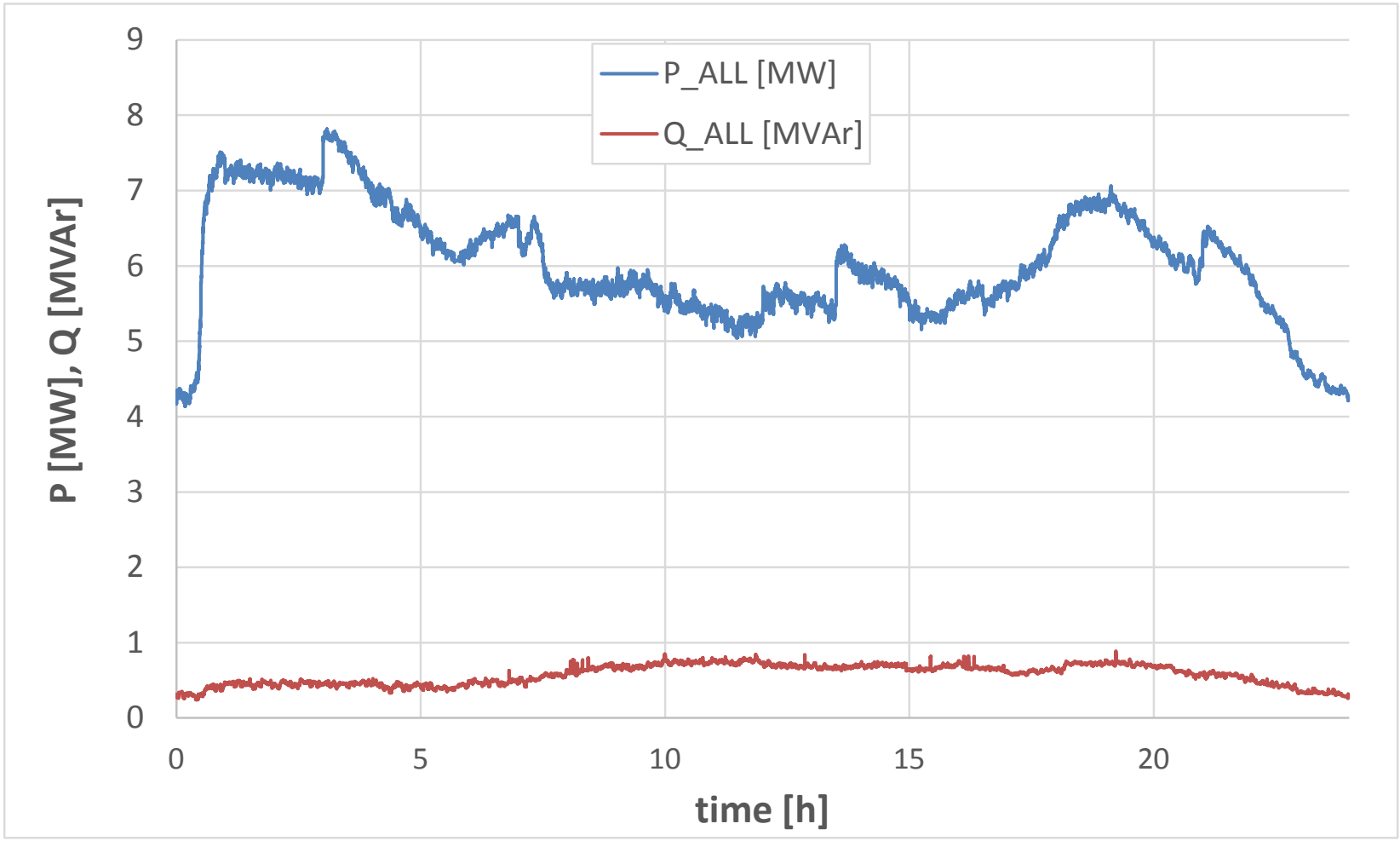


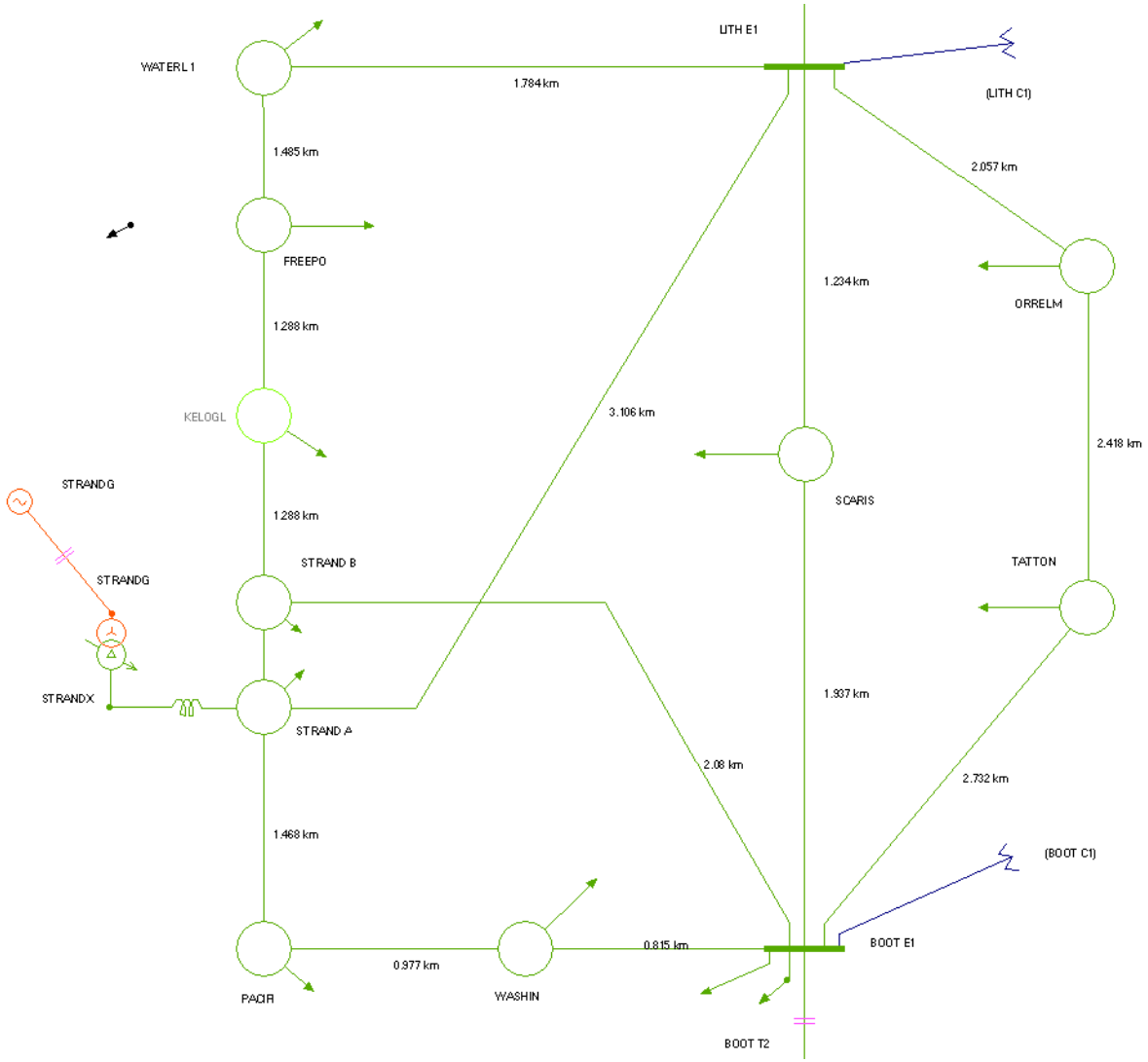
SPM Load Data – Load Case 2

- Combined 3 rural primes – 1 day
- Sampling period 5s – resampled to 1s with linear interpolation



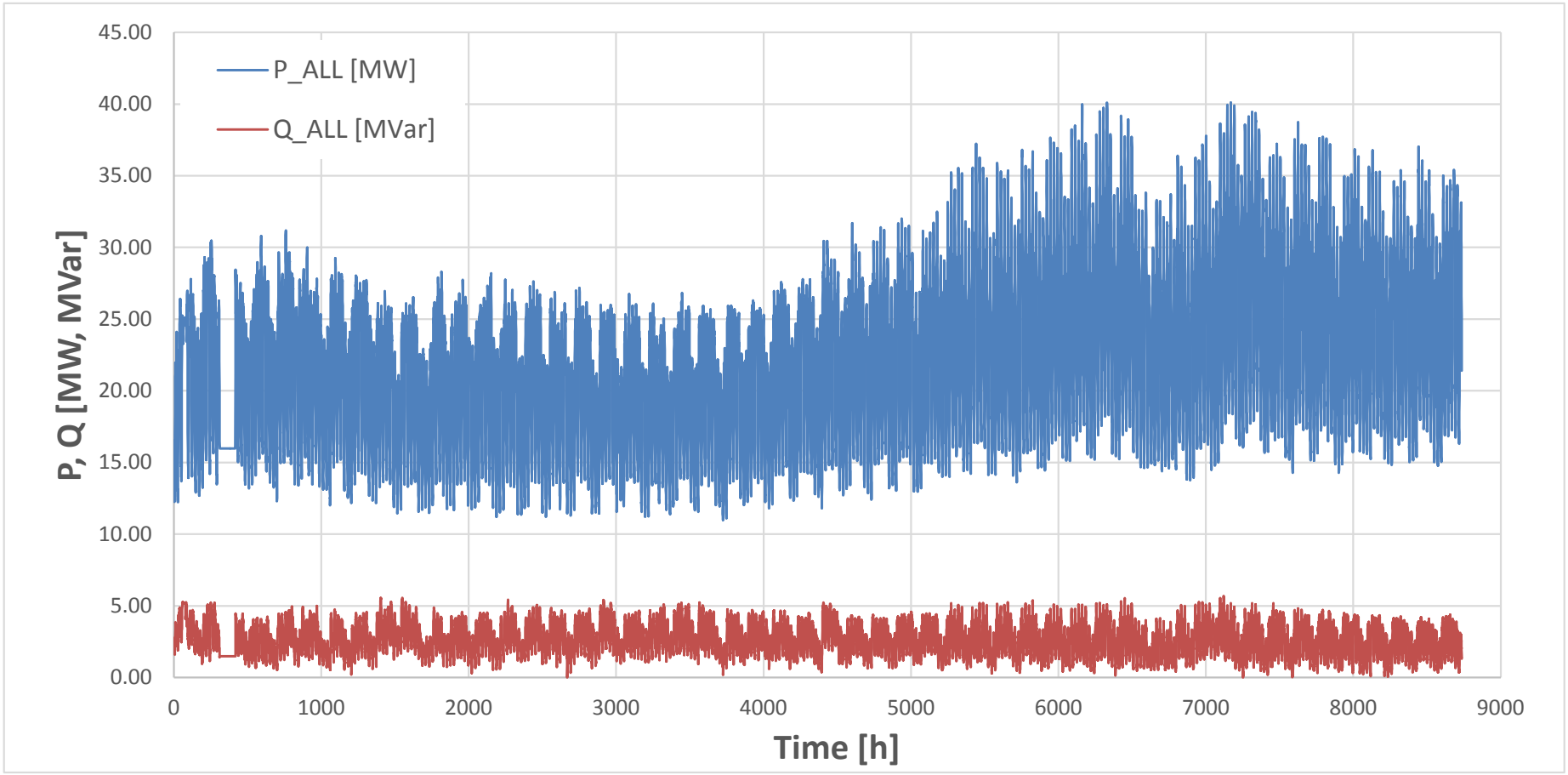
SPM Load Data – Liverpool

- Combined 9 primary transformers (T1,…,T9) – 1 year
- Sampling period 30min



SPM Load Data – Load Case 3

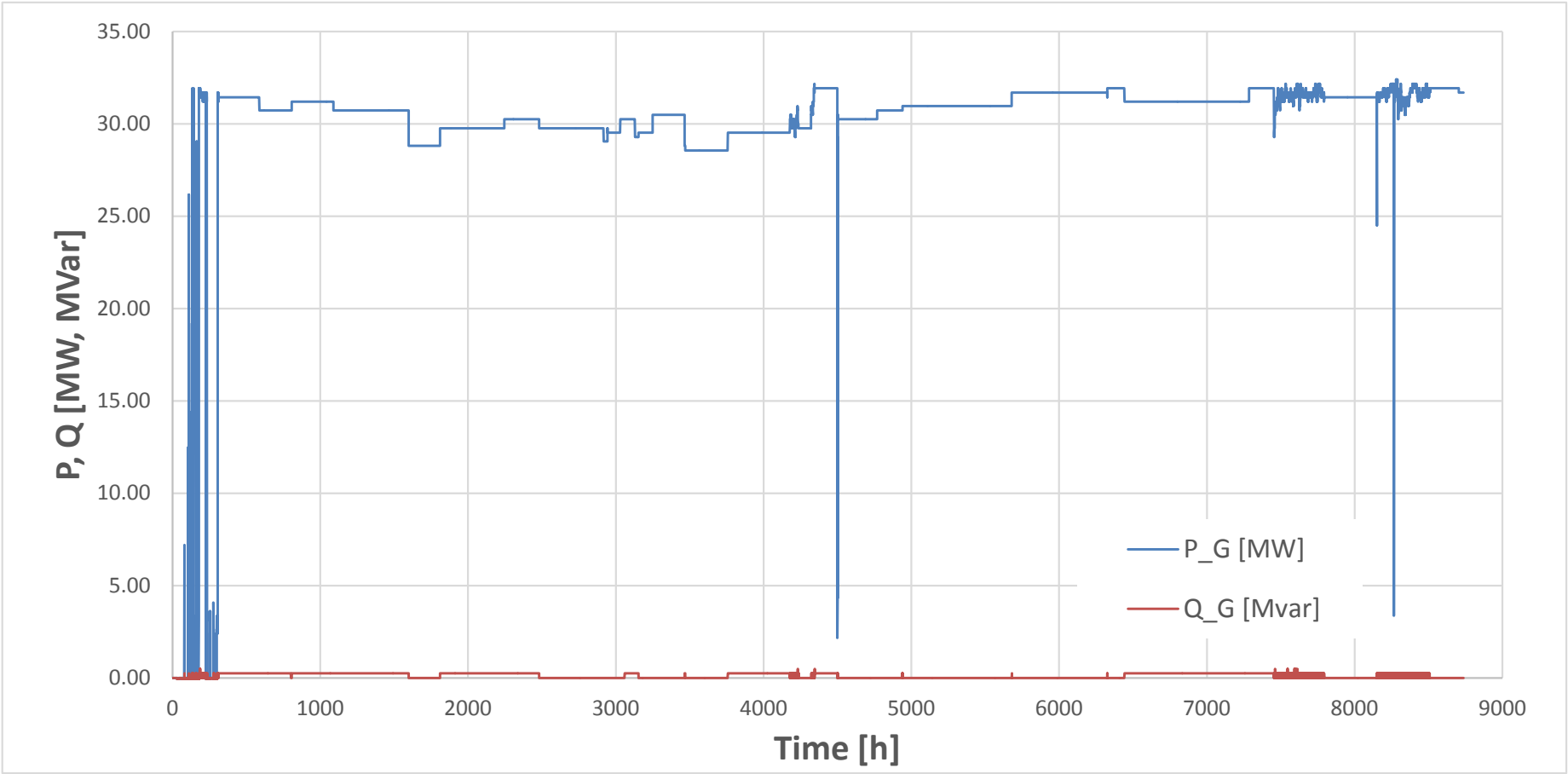
- Combined 9 primary transformers (T1,…,T9) – 1 year
- Sampling period 30min – resampled to 1min with linear interpolation



SPM Generation Data

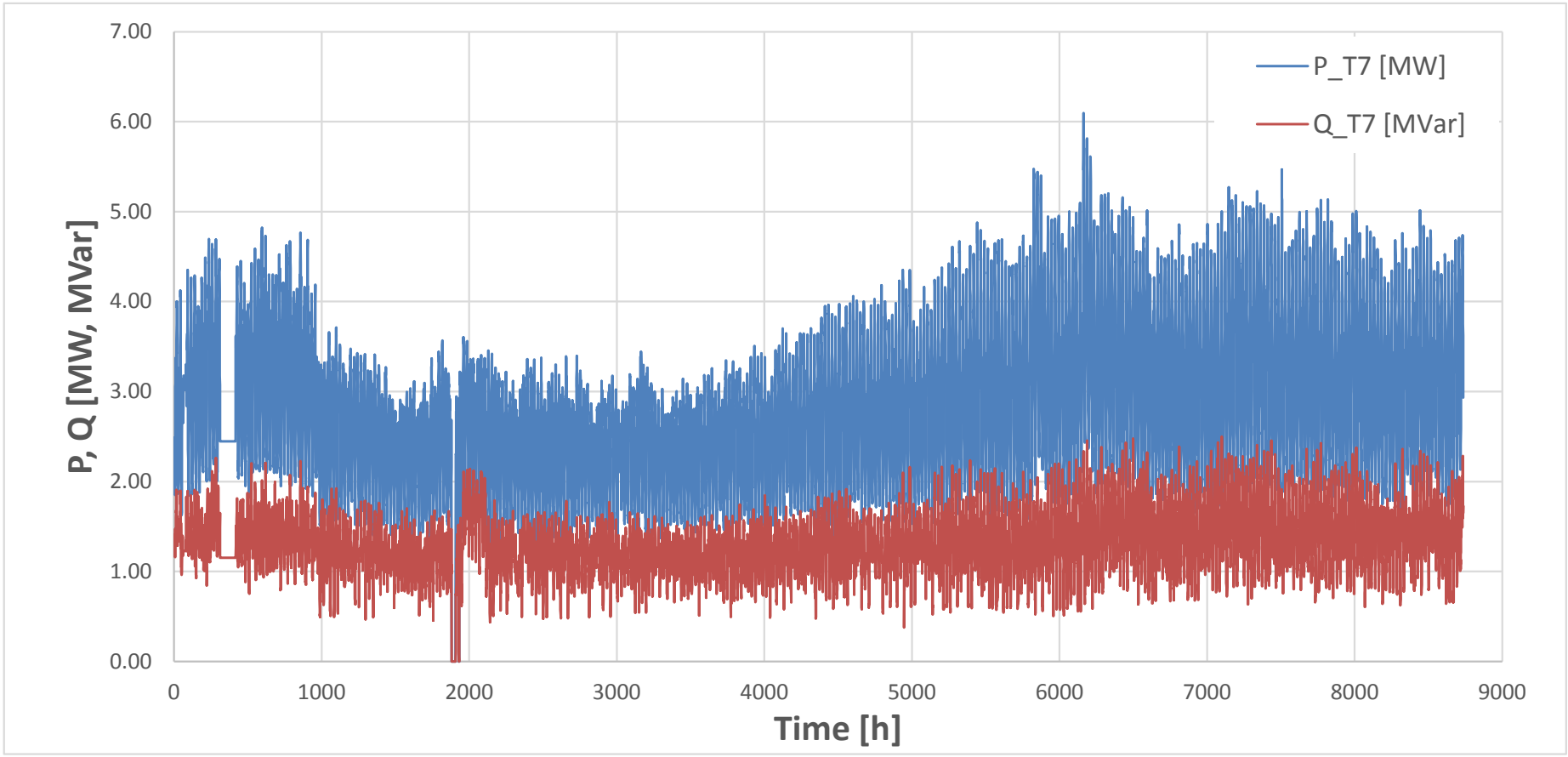
- 30MW DG – 1 year
- Sampling period 30min
- Average pf = 0.994 (lagging)

- Mostly constant output and pf



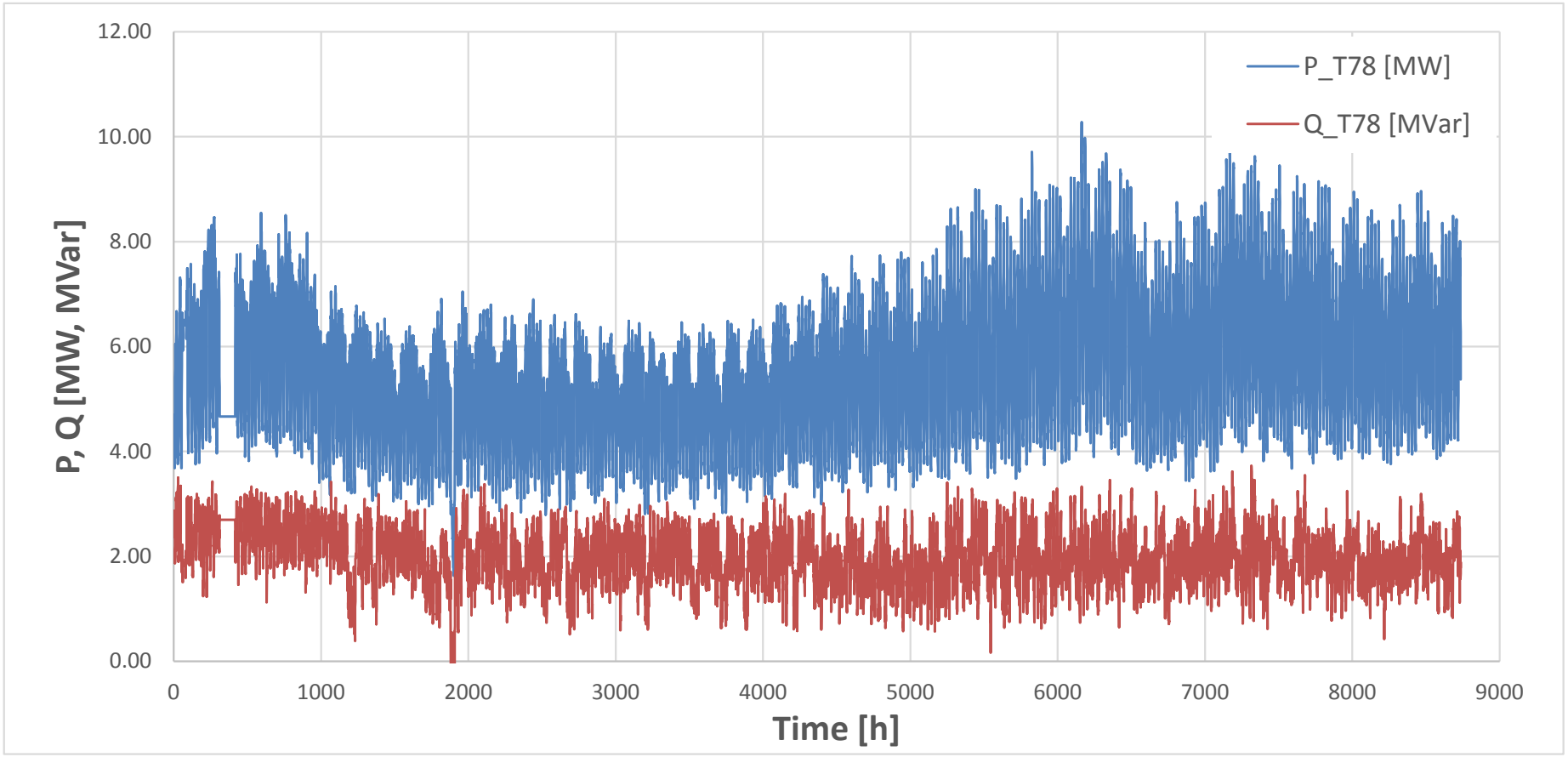
SPM Load Data

- 1 primary transformer (T7) – 1 year
- Sampling period 30min – resampled to 1min with linear interpolation



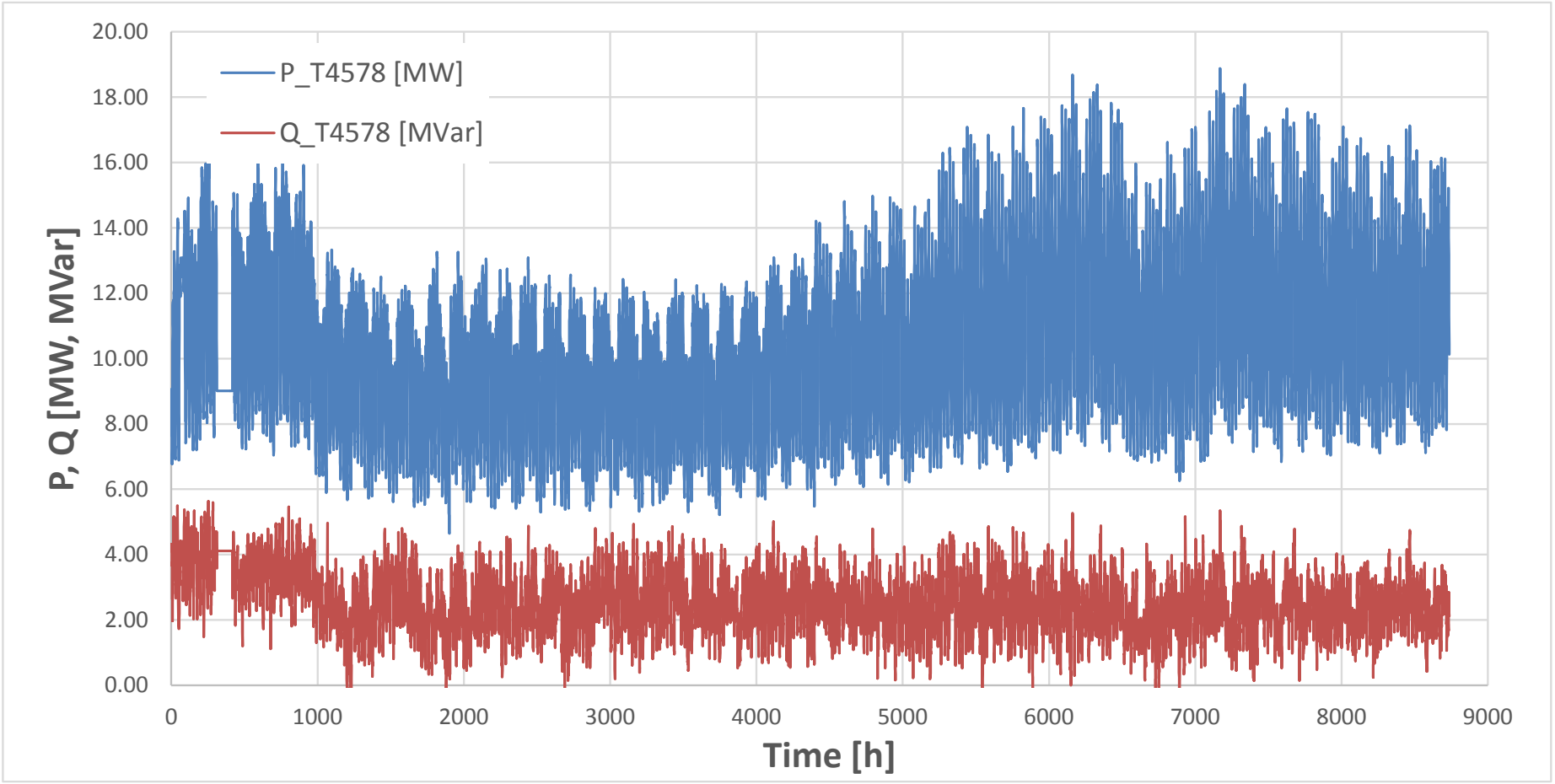
SPM Load Data – Load Case 4

- 2 combined primary transformers (T7, T8) – 1 year
- Sampling period 30min – resampled to 1min with linear interpolation



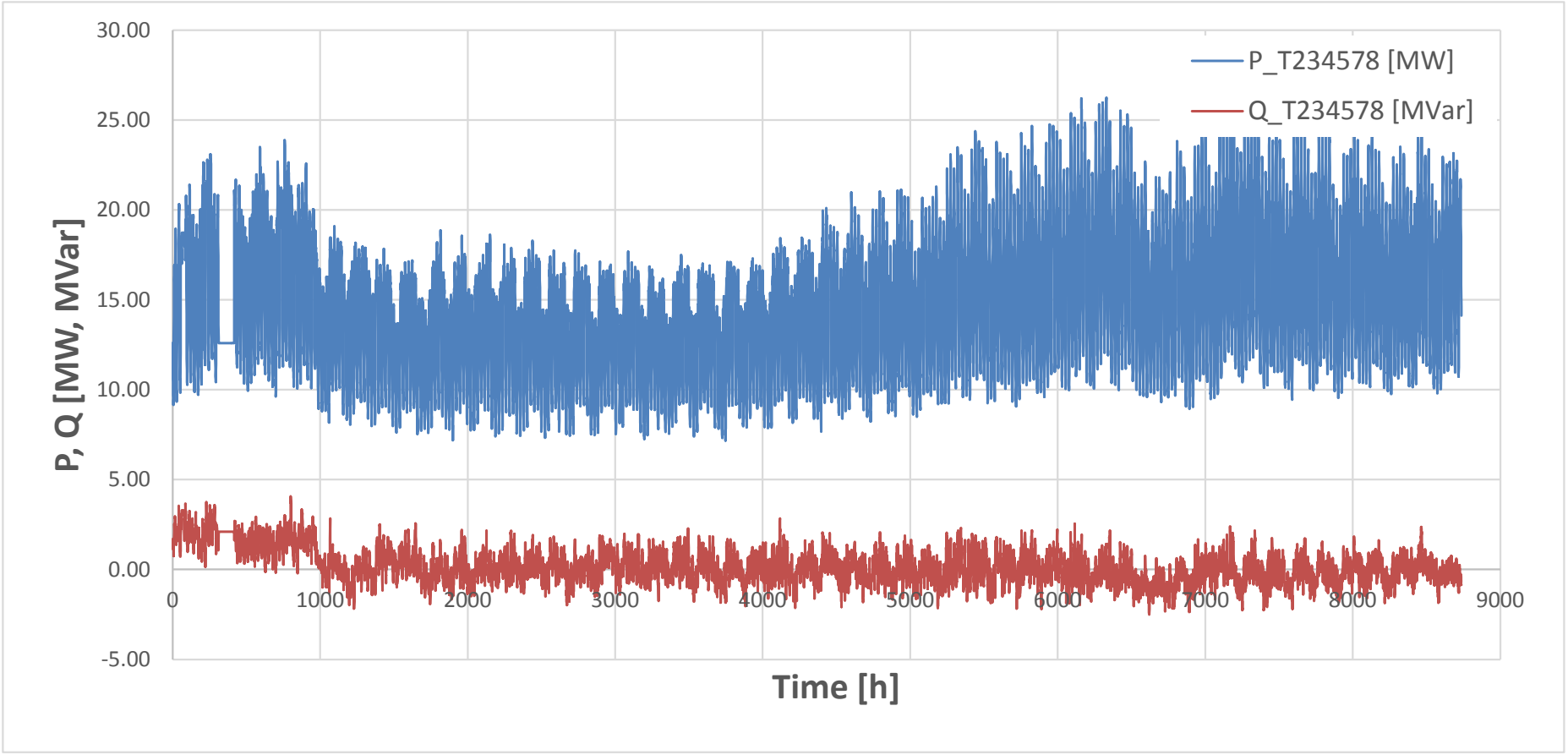
SPM Load Data – Load Case 5

- 4 combined primary transformers (T4, T5, T7, T8) – 1 year
- Sampling period 30min – resampled to 1min with linear interpolation



SPM Load Data – Load Case 6

- 6 combined primary transformers (T2, T3, T4, T5, T7, T8) – 1 year
- Sampling period 30min – resampled to 1min with linear interpolation



Requested data

1) 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. *– more examples received, high resolution data would still be recommended.*
2) 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*
3) Total **number** of primary substations, typical **size** (ideally distribution of sizes) and **frequency of occurrence** of losing a primary substation, i.e. frequency of potential islanding conditions *– continues.*

   ENW – lost supply to primary 11kV or BSP 33kV bars 96 times from 2006 up to the present. These are only the >3 minute events – there will be some (not many) to add on. 350 primary substations; 90 BSPs
4) Current LOM practice for generators between 5MW and 50MW (ROCOF, VS or Intertripping) and estimated amount of DG with ROCOF protection. *– continues*

   ENW – 90%+ of DG has RoCoF... and probably most set to 0.2Hz/s. No intertripping.

Requested data

5) Typical (or average or min/max) size of network fed from a primary substation (i.e. potentially islanded) in terms**,** overall length of lines (cables and OHLs) at 33kV and 11kV, and number of transformers (33/11kV). *– not crucial in Phase I, continues.*

   ENW – downstream of the 33kV bars about 750 33kV circuits; downstream of the 11kV bars we have 3000 11kV circuits. There are 16000 ground mounted substations and 16000 pole mounted transformers. 120000 LV circuits. 2000km of LV OH line; 28500km of LV UG cable 7800km of 11kV OH line; 13000km of HV UK cable 1000km of 33kV OH line; 2200km of 33kV UG cable.

6) Typical DG connections for sizes between 5MW and 50MW (choose from the four types as shown below) *– Discussed at WG meeting. Accurate information not crucial.*

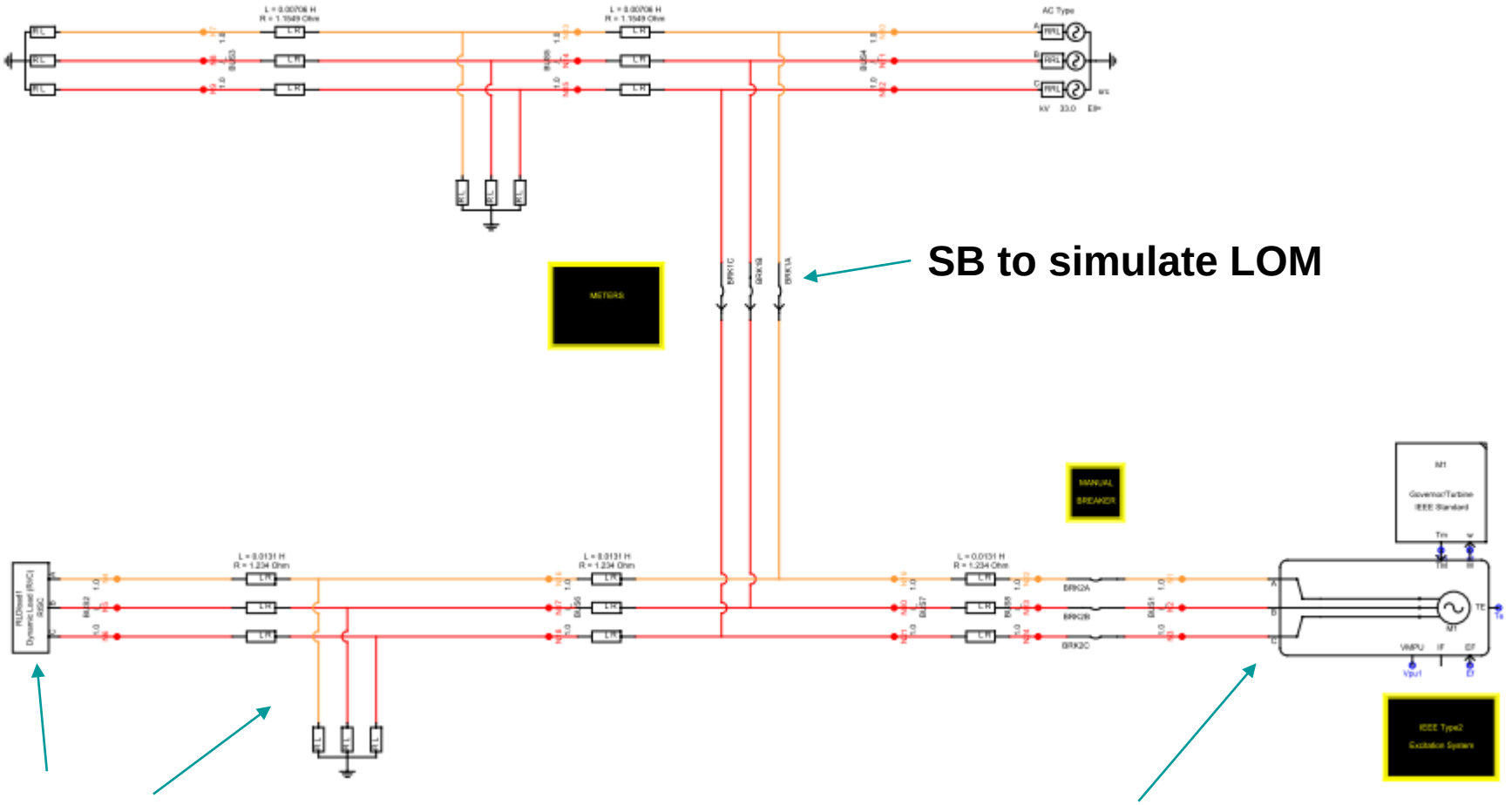
WP1 – NDZ assessment

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 11 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
9	0.12	0.0	No
10	0.13	0.0	No
11	0.2	0.0	No

RTDS Model – network diagram



WP1 – Results (Real Power NDZ)

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Setting Option	ROCOF [Hz/s]	Time Delay [s]	Dead Band applied	NDZ [%]			
				P/V control		P/pf control	
				Fixed power load	Fixed imp. load	Fixed power load	Fixed imp. load
1	0.5	0.0	No	-6.1,5.9			
2	0.5	0.5	No	-7.2,7.2	-7.6,7.6	-7.7,0.0	-0.5,0.6
3	1.0	0.0	No	-12.4,11.5			
4	1.0	0.5	No	-14.6,14.6			
5	0.5	0.0	Yes	-8.4,8.4			
6	0.5	0.5	Yes	-10.6,10.2			
7	1.0	0.0	Yes	-13.1,12.5			
8	1.0	0.5	Yes	-17.7,18.9			
9	0.12	0.0	No	-1.3,1.2			
10	0.13	0.0	No	-1.6,1.5	-1.8,1.8		
11	0.2	0.0	No	-2.4,2.4			

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WP2 – Risk level calculation

WP2 – Risk level calculation at varying NDZ

- Assumptions for preliminary studies
  - Generation range considered 5MW – 50MW
  - Existing Synchronous DG Generation included only
  - 6 different load profiles included
  - Generator output is fixed and *pf*=0.99 (lagging) – based on SPM generation record
  - Max. permissible length of undetected island is 3s.
  - Loss of supply occurrence – 96 times in 7 years a population of 440 substations.
  - P and Q NDZ assumed equal and symmetrical (will be verified with WP1 results later)
  - All SM generators have ROCOF

WP2 – Initial Results

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- Setting option 10 – 0.13Hz/s, 0.0s, No Dead Band
- NDZ=1.8% (assumed for both P and Q)

Load Case	Max load [MW]	Analysed Period [days]	Time step - actual /resampled	$P_{LOM,\,1DG}$ (individual generator)	P_{LOM} (overall)
1	15	6	5s / 1s	$4.55 \cdot 10^{-9}$	$8.33 \cdot 10^{-7}$
2	7.8	1	5s / 1s	$3.75 \cdot 10^{-13}$	$6.86 \cdot 10^{-11}$
3	40	8760	30min / 60s	$5.31 \cdot 10^{-9}$	$9.72 \cdot 10^{-7}$
4	10	8760	30min / 60s	$5.25 \cdot 10^{-10}$	$9.61 \cdot 10^{-8}$
5	19	8760	30min / 60s	$3.20 \cdot 10^{-9}$	$5.85 \cdot 10^{-7}$
6	26	8760	30min / 60s	$2.08 \cdot 10^{-10}$	$3.80 \cdot 10^{-8}$

WP2 – Initial Results

- Setting option 10 – 0.13Hz/s, 0.0s, No Dead Band
- NDZ=1.8% (assumed for both P and Q)

Load Case	pf	NDZ	Network length	T_{NDZavr} [min]	$N_{LOM,1DG}$	$P_{LOM,1DG}$	P_{LOM}
1	-0.99	1.8	0	31.5	7.60661E-05	4.55E-09	8.33E-07
2	-0.99	1.8	0	0.3	8.86524E-07	3.75E-13	6.86E-11
3	-0.99	1.8	0	32.6	8.56412E-05	5.31E-09	9.72E-07
4	-0.99	1.8	0	26.9	1.02714E-05	5.25E-10	9.61E-08
5	-0.99	1.8	0	24.5	6.86107E-05	3.20E-09	5.85E-07
6	-0.99	1.8	0	31.9	3.42315E-06	2.08E-10	3.80E-08

- High risk results especially when low resolution profile is used

WP2 – Initial Results

- Setting option 2 – 0.5Hz/s, 0.5s, No Dead Band
- NDZ=7.6% (assumed for both P and Q)

Load Case	Max load [MW]	Analysed Period [days]	Time step - actual /resampled	$P_{LOM,\,1DG}$ (individual generator)	P_{LOM} (overall)
1	15	6	5s / 1s	$7.76 \cdot 10^{-7}$	$\mathbf{1.42 \cdot 10^{-4}}$
2	7.8	1	5s / 1s	$1.17 \cdot 10^{-8}$	$2.14 \cdot 10^{-6}$
3	40	8760	30min / 60s	$3.07 \cdot 10^{-7}$	$\mathbf{5.63 \cdot 10^{-5}}$
4	10	8760	30min / 60s	$3.54 \cdot 10^{-8}$	$6.48 \cdot 10^{-6}$
5	19	8760	30min / 60s	$2.20 \cdot 10^{-7}$	$\mathbf{4.02 \cdot 10^{-5}}$
6	26	8760	30min / 60s	$3.81 \cdot 10^{-8}$	$6.98 \cdot 10^{-6}$

WP2 – Initial Results

- Setting option 2 – 0.5Hz/s, 0.5s, No Dead Band
- NDZ=7.6% (assumed for both P and Q)

Load Case	pf	NDZ	Network length	T_{NDZavr} [min]	$N_{LOM,1DG}$	$P_{LOM,1DG}$	P_{LOM}
1	-0.99	7.6	0	166.1	0.00245628	7.76E-07	1.42E-04
2	-0.99	7.6	0	3.7	0.00169045	1.17E-08	2.14E-06
3	-0.99	7.6	0	134.1	0.00120577	3.08E-07	5.63E-05
4	-0.99	7.6	0	77.2	0.000241119	3.54E-08	6.48E-06
5	-0.99	7.6	0	103.0	0.00112225	2.20E-07	4.02E-05
6	-0.99	7.6	0	84.9	0.00023623	3.81E-08	6.98E-06

- High risk results especially when low resolution profile is used

WP2 – Initial Results

- Setting option 8 – 1Hz/s, 0.5s, Dead Band 49.5Hz-50.5Hz
- NDZ=18% (assumed for both P and Q)

Load Case	Max load [MW]	Analysed Period [days]	Time step - actual /resampled	$P_{LOM,\,1DG}$ (individual generator)	P_{LOM} (overall)
1	15	6	5s / 1s	$4.47 \cdot 10^{-6}$	$\mathbf{8.18 \cdot 10^{-4}}$
2	7.8	1	5s / 1s	$3.23 \cdot 10^{-8}$	$5.90 \cdot 10^{-6}$
3	40	8760	30min / 60s	$2.08 \cdot 10^{-6}$	$\mathbf{3.80 \cdot 10^{-4}}$
4	10	8760	30min / 60s	$1.04 \cdot 10^{-6}$	$\mathbf{1.90 \cdot 10^{-4}}$
5	19	8760	30min / 60s	$2.66 \cdot 10^{-6}$	$\mathbf{4.86 \cdot 10^{-4}}$
6	26	8760	30min / 60s	$1.50 \cdot 10^{-6}$	$\mathbf{2.75 \cdot 10^{-4}}$

- High risk results especially when low resolution profile is used

WP2 – Initial Results

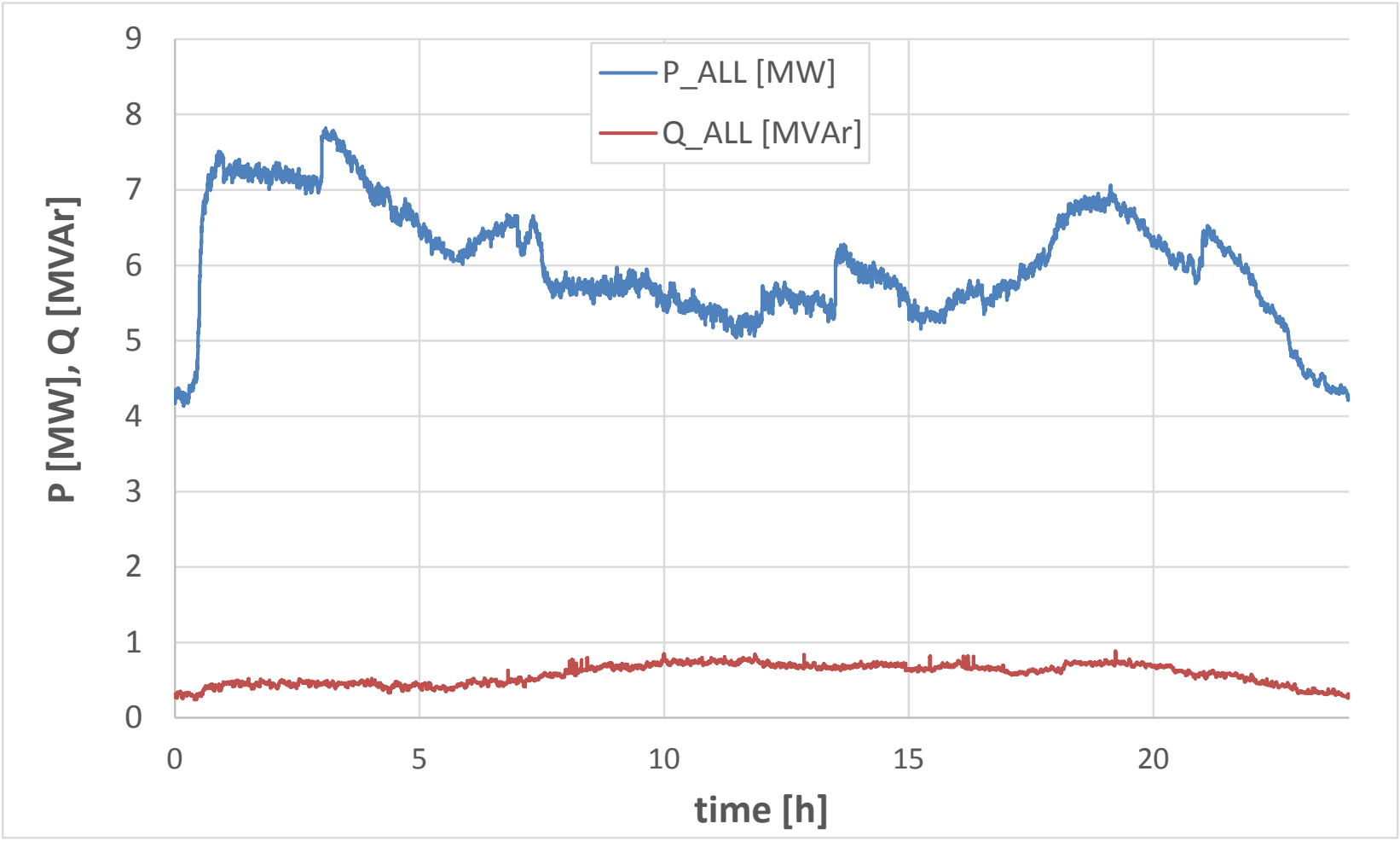
- Setting option 8 – 1Hz/s, 0.5s, Dead Band 49.5Hz-50.5Hz
- NDZ=18% (assumed for both P and Q)

Load Case	pf	NDZ	Network length	T_{NDZavr} [min]	$N_{LOM,1DG}$	$P_{LOM,1DG}$	P_{LOM}
1	-0.99	18	0	405.0	0.00580278	4.47E-06	8.18E-04
2	-0.99	18	0	12.0	0.00142032	3.23E-08	5.90E-06
3	-0.99	18	0	336.4	0.00324589	2.08E-06	3.80E-04
4	-0.99	18	0	208.5	0.0026191	1.04E-06	1.90E-04
5	-0.99	18	0	272.9	0.00512102	2.66E-06	4.86E-04
6	-0.99	18	0	225.4	0.00349866	1.50E-06	2.75E-04

- High risk results especially when low resolution profile is used

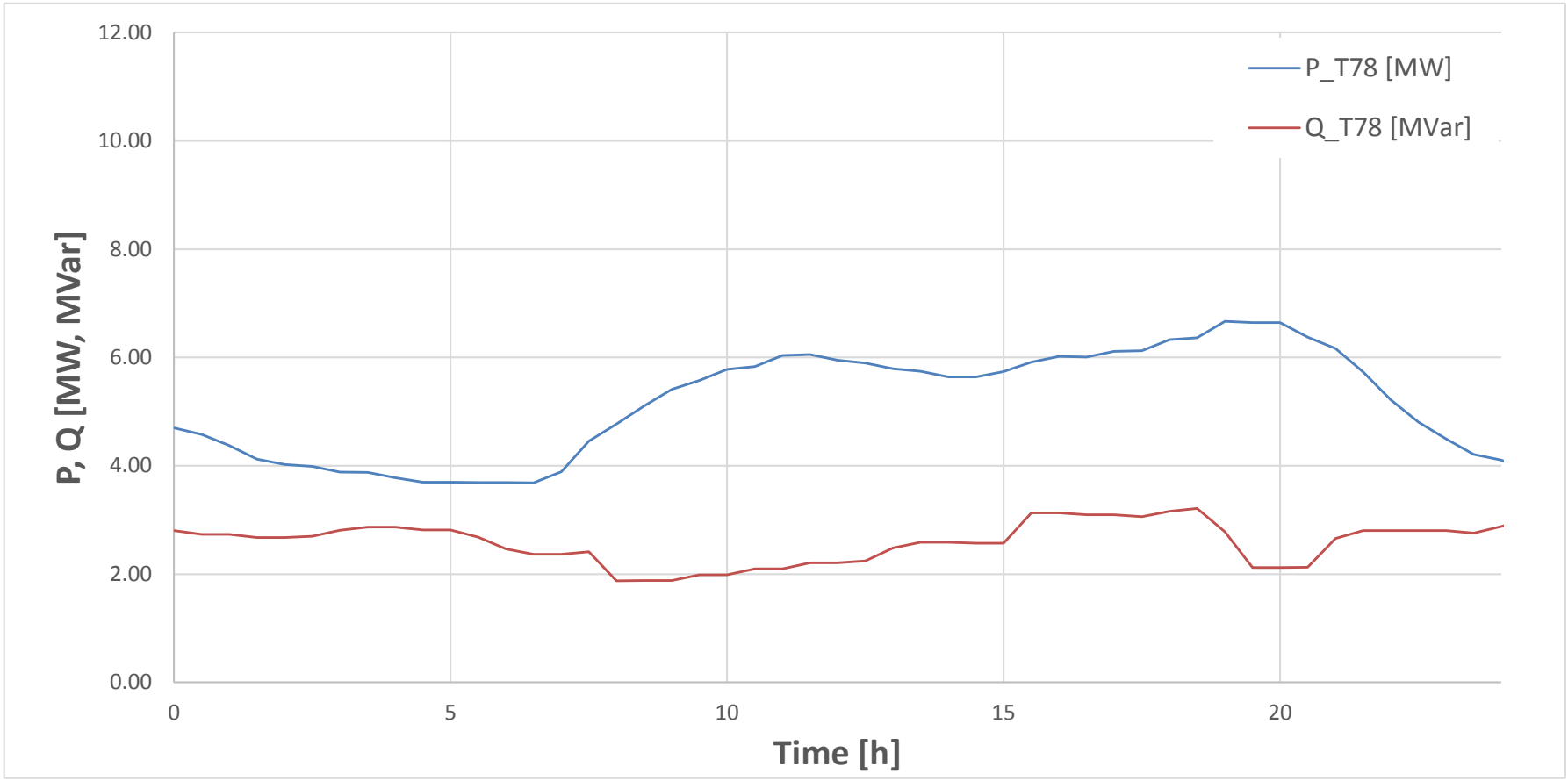
SPM Load Data – Load Case 2

- Combined 3 rural primes – 1 day
- Sampling period 5s – resampled to 1s with linear interpolation



SPM Load Data

- 2 combined primary transformers (T7, T8) – 1 day
- Sampling period 30min – resampled to 1min with linear interpolation



What level of risk can be accepted?

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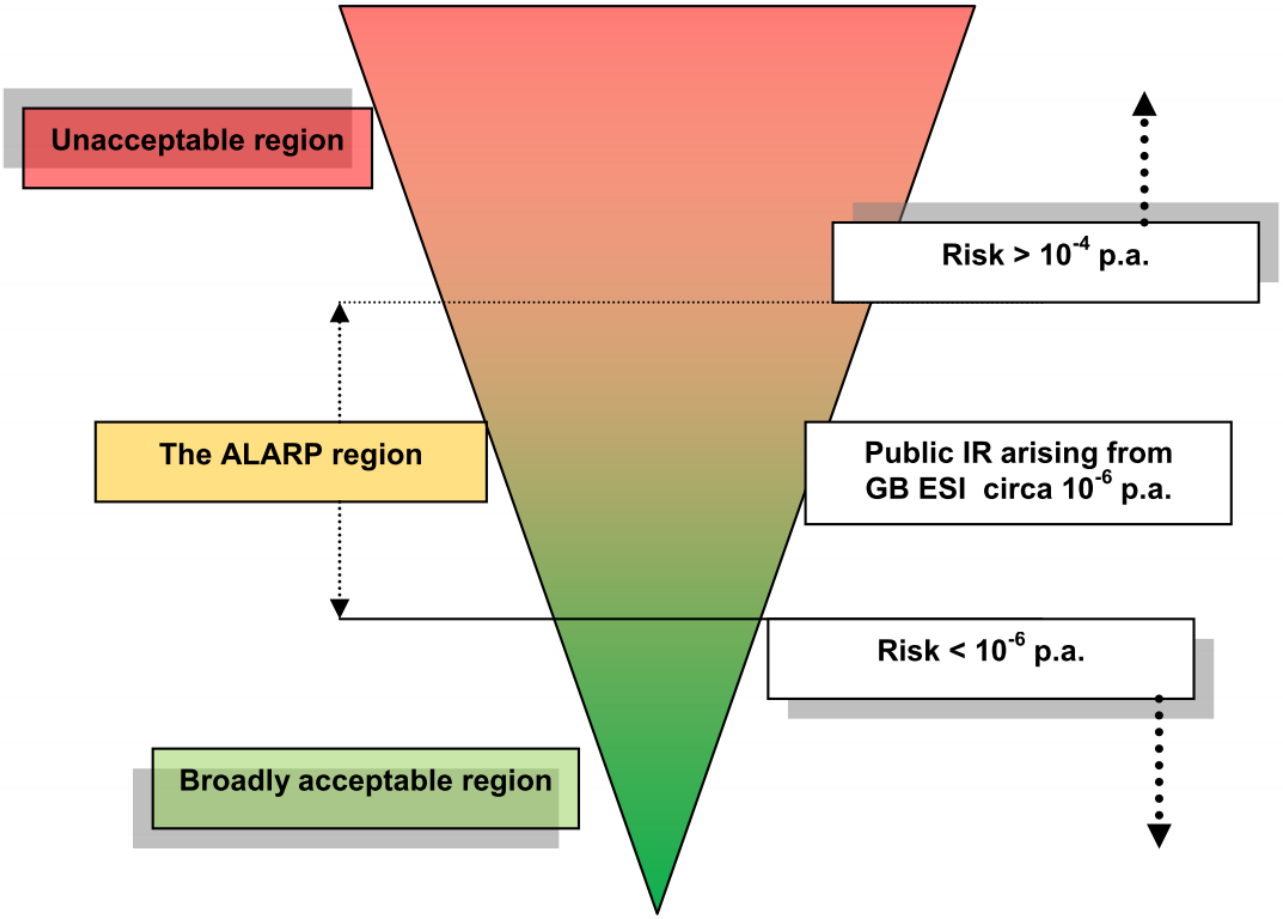
Health and Safety at Work Act 1974



Progress summary

- Samples of load profiles have been obtained and analysed
- WP1: NDZ assessment is ongoing – NDZ may be as high as 18% for ROCOF setting of 1Hz/s, delay of 0.5s and Dead Band enabled.
- WP2: Risk assessment is ongoing – some results reach unacceptable risk level, but this is likely to be due to low resolution of the load data. More high resolution data is needed to verify this.

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Thank you!