Risk Assessment of Loss of Mains Protection

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Outline

- Proposed methodology
- Comments on the proposal

Methodology

Assume network configuration, load profile, and generation technology

NDZ knowledge base

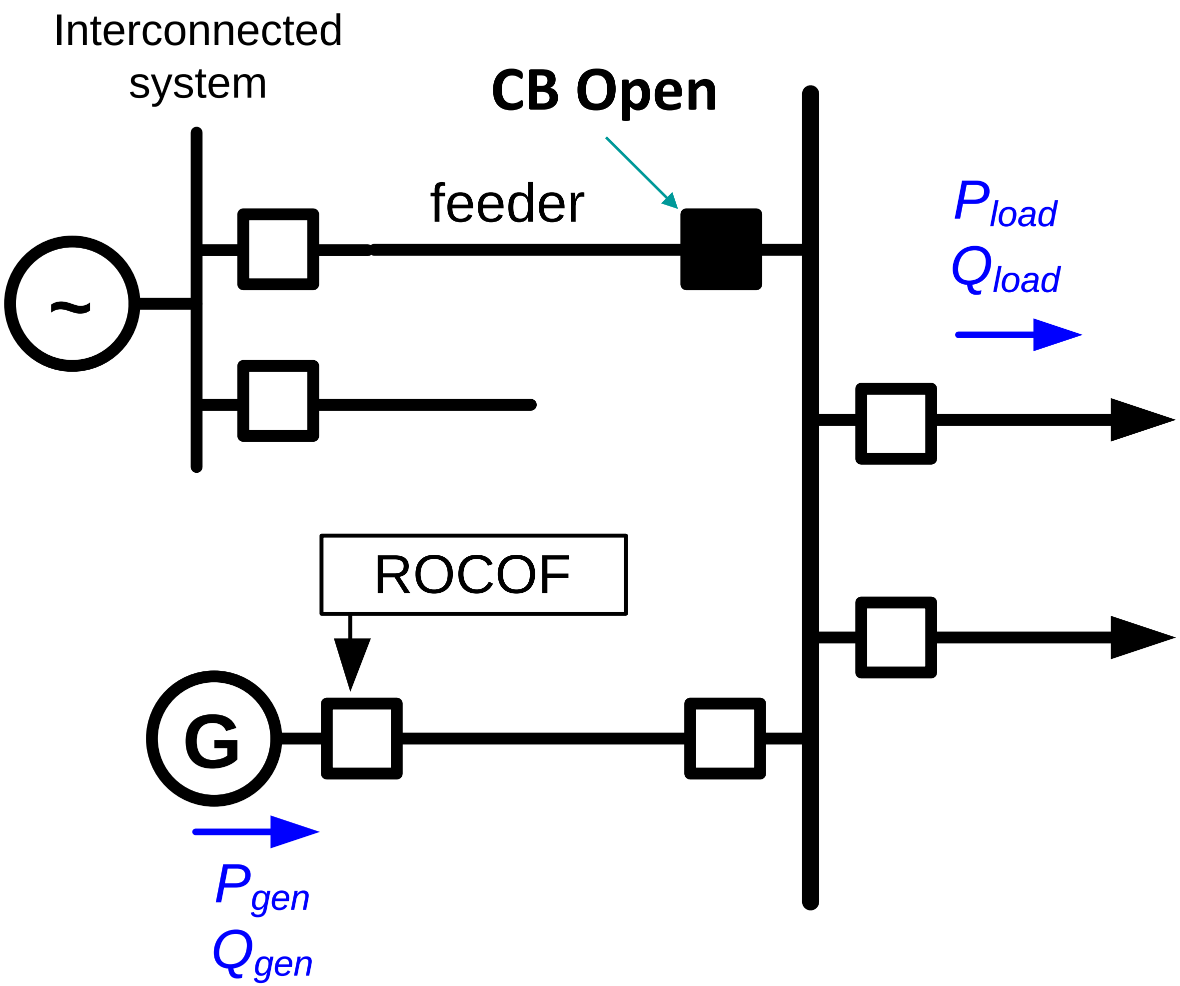
ROCOF NDZ assessment under proposed new settings (lab testing, simulation, literature review)

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

risk assessment based on probability tree

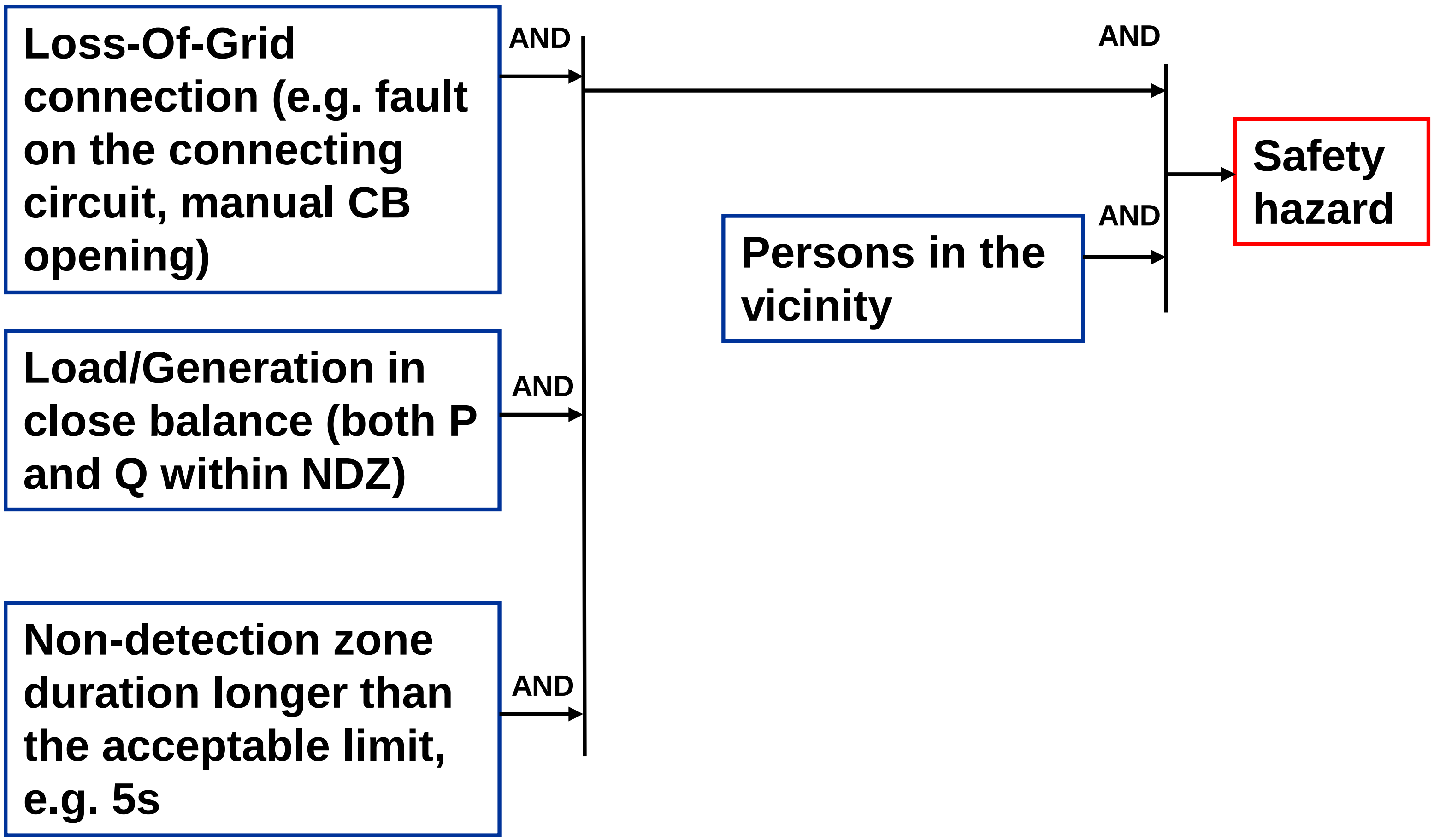
Individual risk.

Lab based assessment of Non-Detection Zone (NDZ)

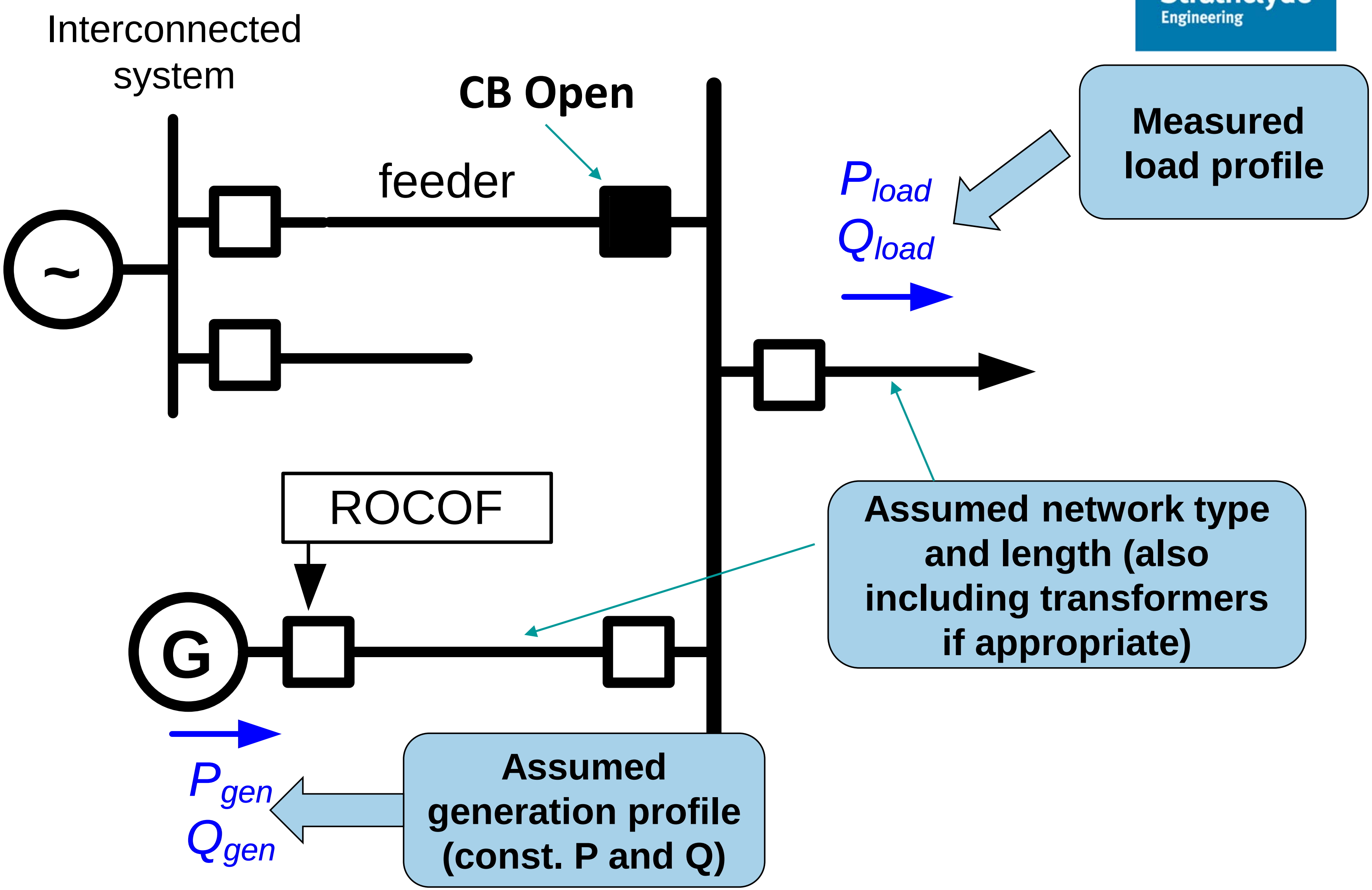


1. Consider load and generation model (including control)
2. Apply proposed relay setting option.
3. Establish real power NDZ (Q in balance) by adjusting P_{load}
4. Establish reactive power NDZ (P in balance) by adjusting Q_{load}

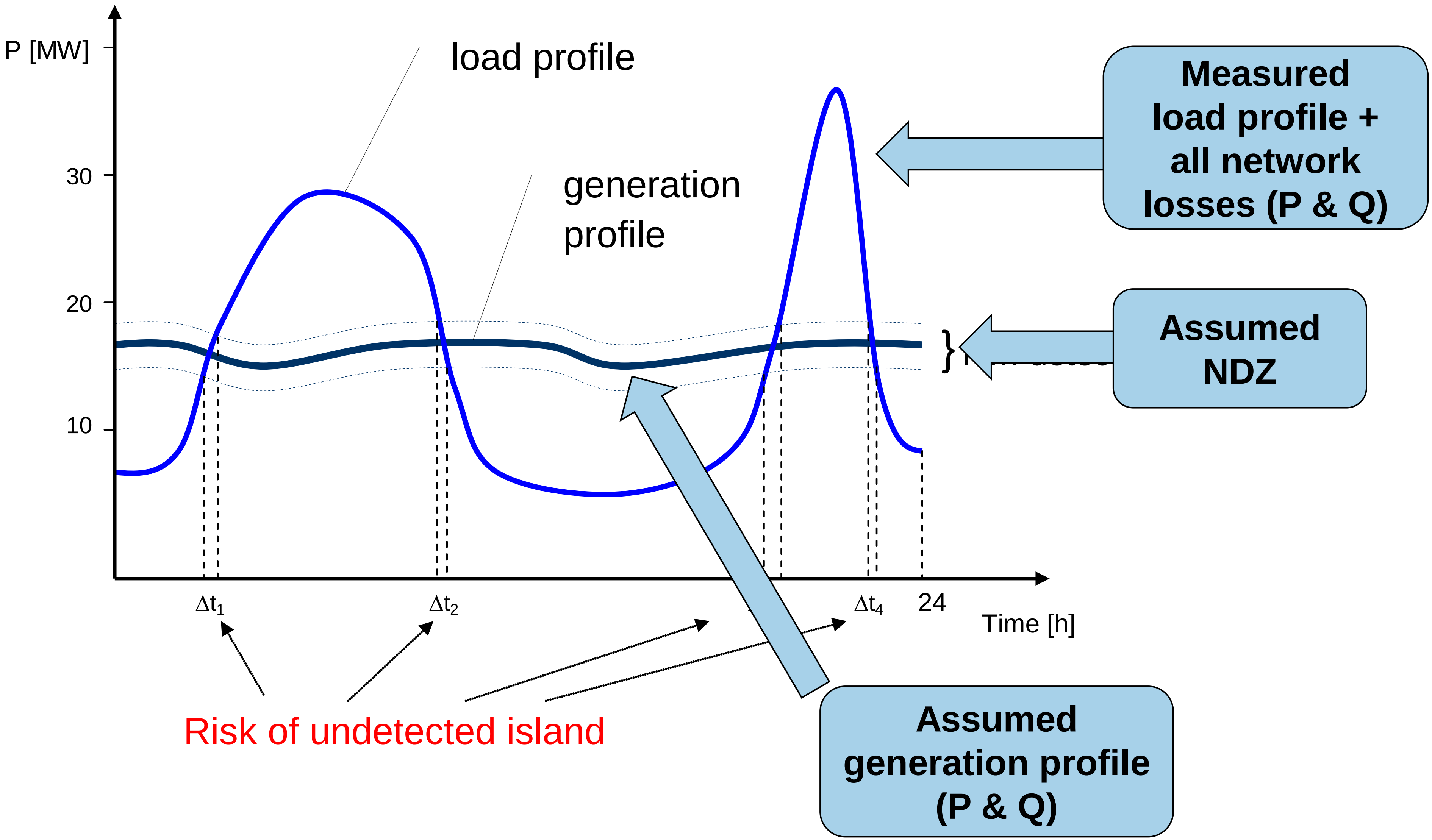
LOM Safety Hazard Probability Tree



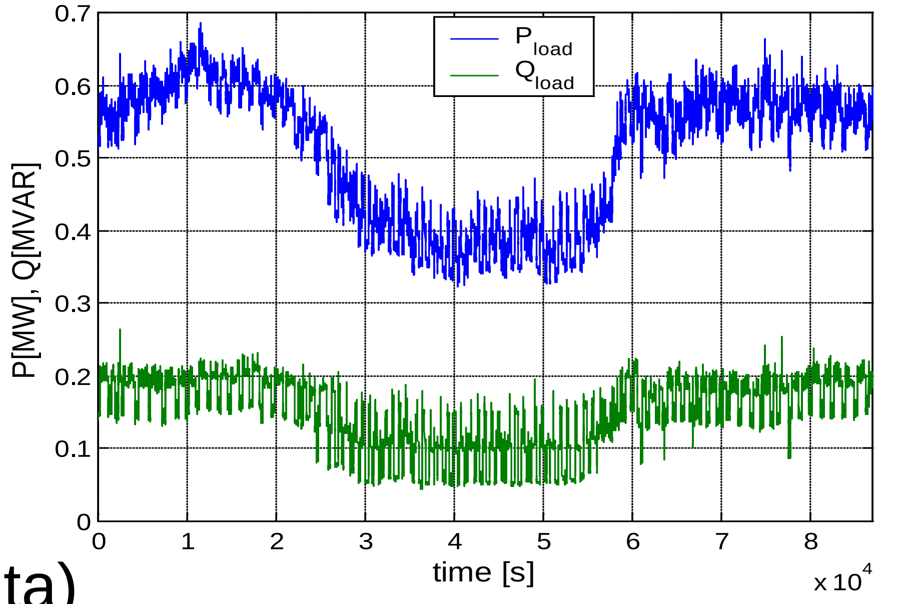
Network model for the probability tree



Probability of Load/Generation matching



Assumptions



- Load profile (e.g. ENW 11kV data)
- Network type and length of circuits
- P and Q non-detection zone (from NDZ repository)
- Maximum acceptable non-detection zone duration (e.g. T_{NDZmax} = 5s)
- Generator size and mode of operation (e.g. generator

  at 0.98pf - lead)

Randomising the assumptions

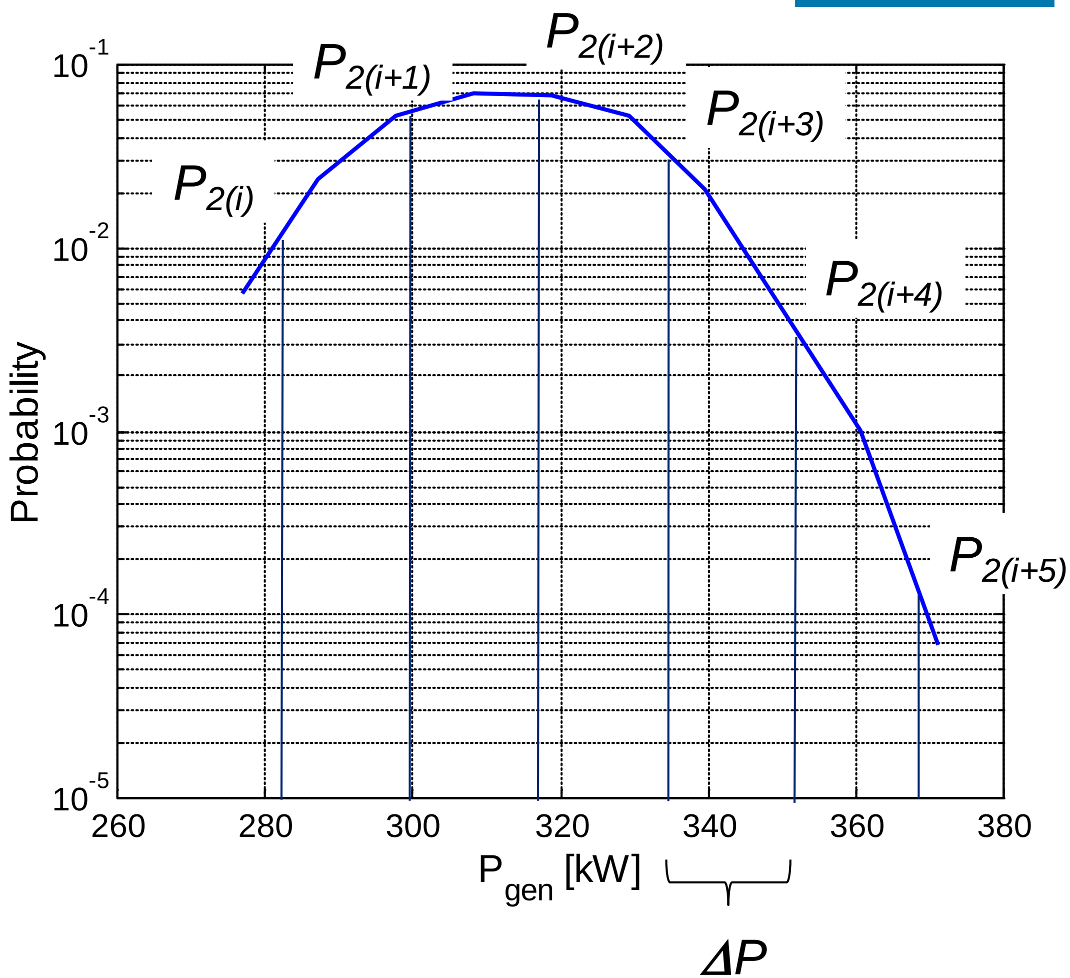
- Each assumption can be:
  - **Fixed** (representing typical or worst case scenario)

    Applicable when there is no information available or the variable does not have significant impact on the final result.
  - Treated as a **random variable** (probability distribution of a specific condition needs to be assumed).

    Applicable when the assumption has a wide range of values and there is a significant impact on the final result.

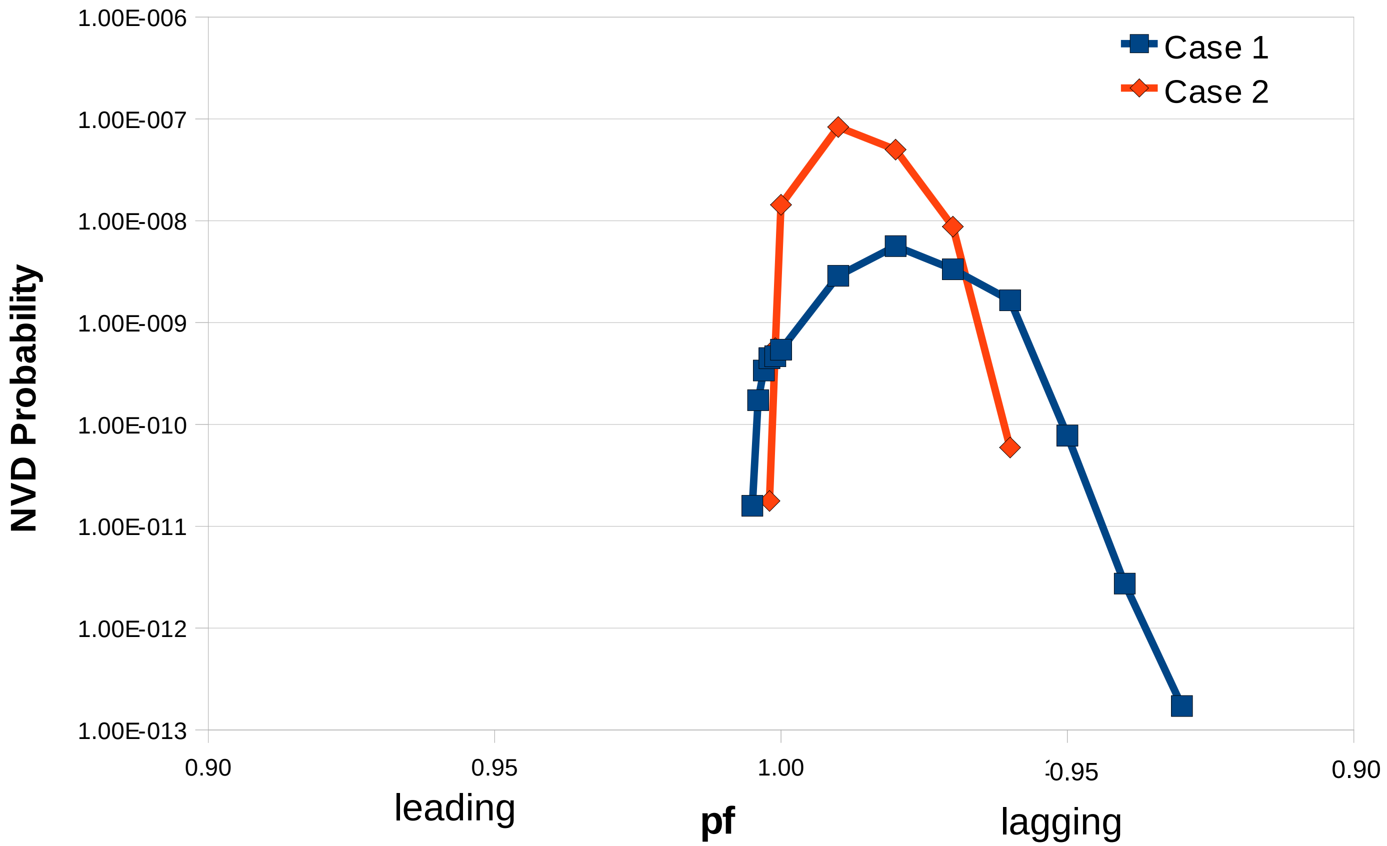
Randomising generator size

- Marginal probability principle is used for calculating overall probabiliy



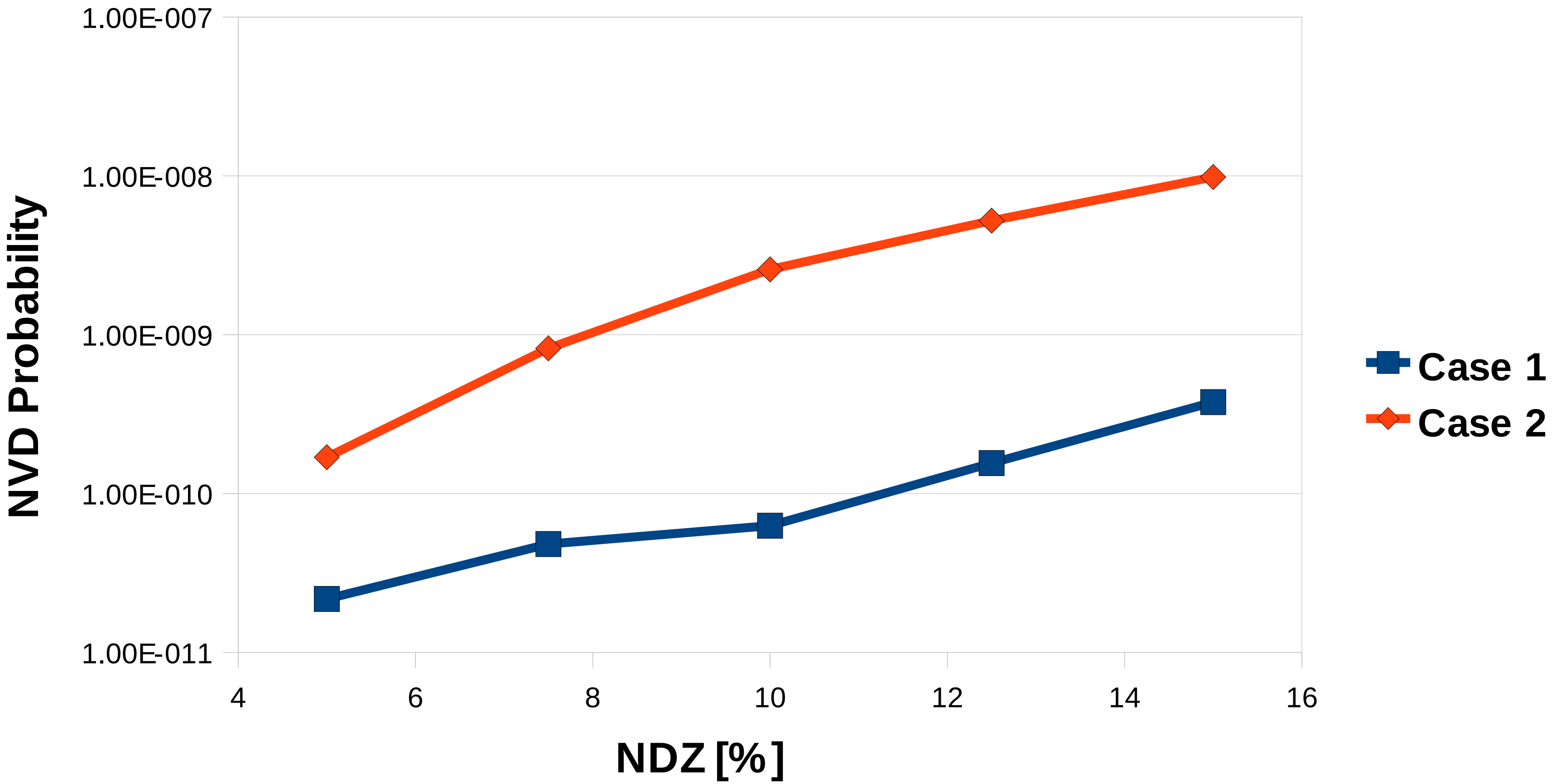
Non-detection zone probability at varying levels of generator output

Impact of machine power factor



There is a certain value of *pf* where the probability reaches maximum. The total probability (national figure) will depend on how many generators can be expected to operate in this range of *pf*, i.e. between 1 and 0.95 lag. The range is shifted depending on the total length of the islanded network, i.e. for longer lines (more capacitance) the plots shift to the left (and vice versa).

Impact of NDZ (NVD study)



The result shows that for every 5% of NDZ the estimated risk probability increases approximately by one order of magnitude.

Discussion

- **Starting frequency for scenarios with dead band applied – SSE**
- *“Application of a dead band with no operation will have little effect at 1Hz per second over half a second unless the frequency is significantly above 50Hz at the start of the test. However with 0.5Hz per second there is quite a large chance that the dead band will prevent operation and potentially allow an island to be established. I'm not clear how this uncertainty is to be dealt with but otherwise I'm happy with the proposal.”*

- It is a good point. The starting frequency will be one of the factors to consider in scenarios 5-8 of Table 1. Perhaps 3-5 starting points should be considered. Additionally, some statistics can be derived from the available PMU data to establish typical frequency distribution in UK and then calculated a *weighted* NDZ.

Discussion

- **Size and connection of the machine – SP**
- *"SP has concerns with regards to the number of test scenarios proposed and whether this adequately covers off all the DG connections that we currently have on the distribution network.*
- *A 3MVA machine would most likely be connected to the hV busbar at a Primary Substation and as a result have a more remote risk of becoming islanded. We also have visibility of connected demand at Primary Substation level which should in theory allow us to look at the risk of islanding at the design stage.*
- *We are seeing progressively more & more smaller machines connecting to distribution networks. It is at these more dispersed connections we have far less information of the anticipated demand and due to their less robust connection arrangements they are also at far greater risk of islanding."*

- Size of the machine is fixed to 3MVA only for the NVD assessment exercise purposes. The size is then randomised at the risk assessment stage.

Discussion

- **Test scenario coverage – SP**
- *"I appreciate that the scope of works will carry out 'spot checks' on other generating technologies should we also not be expanding this to look other connection arrangements these should include :*
  1) *Direct connection to the hV busbar at a primary Substation.*
  2) *Connected at hV at a point some distance from the Primary Substation (up to 500 kW)*
  3) *Multiply DG connections (2 or more) on a radial fed hV network.*
  4) *Connection at LV (up to 100 kW / high level of PV)."*

- Typical scenarios like these can be considered at the risk assessment stage where specific networks, load and generation configurations will be assumed. It is proposed to define (in consultation with DNOs) a few most common representative setups and assess relative proportion in the total DG installed capacity (if known).

Discussion

- **Test scenario coverage – WPD**
- *"Whilst I understand the need to limit the scope of the studies I do not think the proposal, as it stands, accurately reflects the current situation. Assuming the ROCOF changes will apply to generators of different types and sizes, connected at different voltage levels, should the studies be expanded to include multiple generator connections and generators connected at LV?*

- The approach taken in the study is to try to limit the cases to a few typical or worst case (i.e. most stable) scenarios which admittedly can lead to somewhat overestimated risk. This can be addressed by considering a few agreed network and generation configurations in the risk probability calculation stage.

Discussion

- **Validity of the model – WPD**
- *"It should be noted that some DNOs questioned the validity of Strathclyde's original work on NVD protection simply because the studies were so limited in scope. The result of this is that many DNOs still insist on installing NVD protection, even where generators do not operate in voltage control mode. If DNOs are not confident in the results from this work it is possible that they may specify other, more expensive forms of loss of mains protection, such as intertripping."*

- I believe the assumptions taken for the NVD study have been explained and discussed during the WG meetings but perhaps not accepted by all. The challenge is how to present the work in a convincing way so that necessary simplifications are understood and accepted.
- It is worth noting that after relaxing ROCOF settings the need for NVD may become more justified and can perhaps be helpful to reduce the overall risk of undetected LOM.

Discussion

- **Validity of the model**
- *"My detailed concerns / comments on the proposal relate to:*
  - *The suitability of the models used to undertake the NVD modelling in 2009*
  - *The transparency of these models*
  - *The treatment of multiple generators on part of a network*
  - *The enduring nature of any emerging solution / conclusion"*
- It was assumed that SM generator is the most stable generating technology with DFIG, Induction and Inverter based generators perceived as less stable. This may not always be true now (test results from Spain demonstrate stable islands with inverter based PV generation). The issue is highlighted to be specifically addressed in the proposal but may need expansion (e.g. laboratory testing). We have a few Windy Boy inverters and a Fronious inverter. Other inverters can also be connected and tested in the Strathclyde Microgrid Lab where islanded operation can be setup.

Discussion

- **Other setting options – WPD**
- *"Given that the draft version of CENELEC Document CLC/FptTS 50549-1 and 50549-2 requires generating units to be able to operate with rates of change of frequency of up to 2.5Hz/s (clause 4.6.1) should the ROCOF proposal also look at the impact of changing the setting to 2.5Hz/s? Also, would it be worth studying the impact of removing ROCOF protection completely and relying on over/under voltage, over/under frequency and other forms of loss of mains protection such as Vector Shift?"*

- I think removing the ROCOF completely is a good option to study for future reference. 2.5Hz/s should probably give similar result to removing ROCOF. VS could be studied but earlier tests showed it is not very sensitive even with 6deg setting.

Thank you!