Mitigation of the Rate of Change of Frequency (RoCoF).

“A unique threshold of 2 Hz/sec is impossible.”

What are the next steps?

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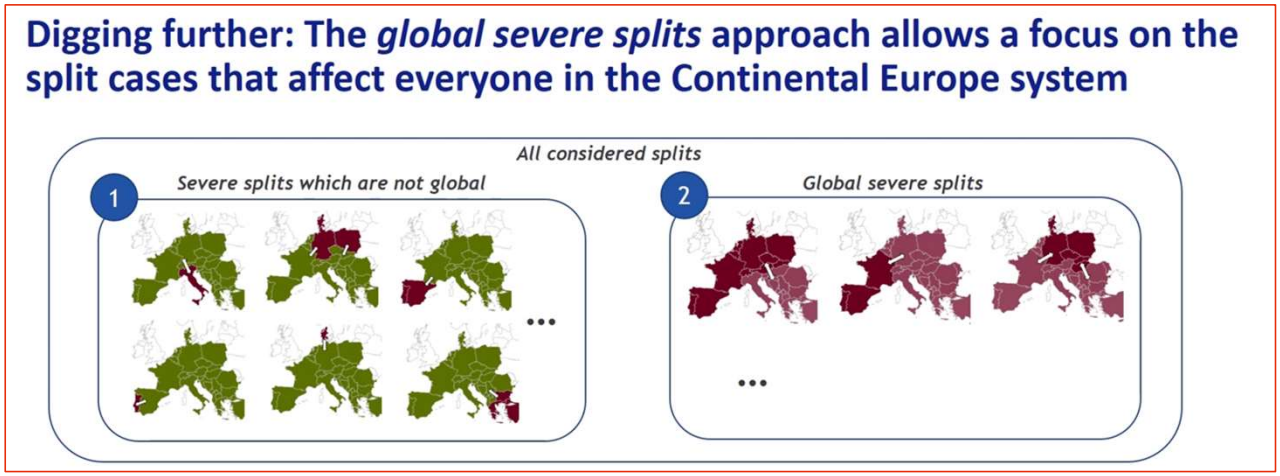
ENERGY IS US

Content of this presentation

At a workshop organised by ENTSO-E on 1 February 2022 several studies demonstrated that the RoCoF due to a system split will increase in the future.

Following slide was most explicit demonstrating the danger for a general black-out.



A next step is needed to define countermeasures limiting the RoCoF at a reasonable value.

In this presentation arguments for this next step are demonstrated.

Specifications in the RfG NC

For NEW installations, following items are specified in the RfG NC (REGULATION (EU) 2016/631)

Recital (25) : *Synchronous power-generating modules have an inherent capability to resist or slow down frequency deviations, a characteristic which many RES technologies do not have. Therefore countermeasures should be adopted, to avoid a larger rate of change of frequency during high RES production. Synthetic inertia could facilitate further expansion of RES, which do not naturally contribute to inertia.*

Art. 13.1.b : *With regard to the rate of change of frequency withstand capability, a power-generating module shall be capable of staying connected to the network and operate at rates of change of frequency up to a value specified by the relevant TSO, …*

But some countries impose or are planning to impose following requirements for new power plants:

- +/-2,0 Hz/s with a sliding window of 0,5 s AND
- +/-1,5 Hz/s with a sliding window 1,0 s AND
- +/-1,25 Hz/s with a sliding window 2,0 s

vgbe is convinced that those figures are NOT consistent with recital 25.

What about positive and negative RoCoF values in a sliding window with very low average value?

Nothing is specified for existing installations because at the time of their design, the RoCoF was not an issue.

Data of papers published by ENTSO-E

The definition of the RoCoF used by ENTSO-E is described in the paper “Frequency Measurement Requirements and Usage Final Version 7” dated 29/1/2018 :

For an accurate RoCoF calculation experience has shown that a sliding window over approximatively five consecutive measurements gives robust results which in the case of 100 ms time resolution results in 0.5 seconds time required before a reliable RoCoF value can be available.

IS THIS DEFINITION ACCEPTED BY ALL STAKEHOLDERS? CAN IT BE OFFICIALISED BY ENTSO-E? WHAT ABOUT THE REQUIREMENTS IN SOME COUNTRIES FOR 1 SEC AND 2 SEC?

In the paper “Inertia and Rate of change of Frequency” dated 16/12/2020 is written :

The lower graphs show transients with RoCoF higher than 1 Hz/s; all these events ended with fast grid collapse, due to the incapacity of regulations and defense systems to trigger in time and counteract the transient. Therefore, we can deterministically conclude that transients with RoCoF higher than 1 Hz/s are not manageable by system protections; this limit is related to the minimum time to measure the phenomena in a stable and secure way and react by opening the circuit breakers of loads or generation. It seems that the current technology does not guarantee correct operation of protection equipment in the presence of this kind of transients.

WHY ARE THRESHOLDS ABOVE 1 Hz/sec IMPOSED????

DNV-KEMA Study dated 8/2/2013 by order of Eirgrid

Generation Units Result Summary					1 Hz total frequency drop			
Generator Set	Unit Size	Inertia Constant H	Xd	Terminal Voltage	Stable	during	RoCoF	
[name]	[MW]	[Sec.]	[p.u.]	[kV]	[@ 0.5 Hz/s]	[@ 1.0 Hz/s]	[@ 1.5 Hz/s]	[@ 2.0Hz/s]
CCGT Single-shaft	400	5.5	1.9	20	Y	Y*	Y*	N
CCGT Dual-Shaft	260	6	2.3	17	Y	N	N	N
CCGT Dual-Shaft	140	9	2.1	17	Y	N	N	N
Steam Thermal (Reheat)	300	5	1.7	17	Y	Y*	Y*	N**
Steam Thermal (Once Through)	250	4.5	2.3	20	Y*	Y*	N	N
Steam Thermal (Fluidized bed peat)	150	8	2.2	11	Y*	N	N	N
OCGT	50	1.5	2.9	11	Y*	Y*	Y*	Y*
Salient-pole Hydro	30	2.7	1.4	11	Y	Y	Y	Y

The tables give a general overview of the findings where:

Y is used to indicate stable operation

Y* is used where a pole slip is only observed for a 0.93 leading power factor operation mode;

N is used when a pole slip is also observed for power factors of 1 unity or/and 0.85 lag;

N** is used when no pole slip is observed for power factors of 1 unity or/and 0.85 lag but negative power generation is detected.

Conclusion :

Several types of power plants do not support a RoCoF above 1 Hz/sec

Comments at the EUTurbines paper (Febr. 2022) about the RoCoF

Statements accepted by vbge:

- *During fault ride through events, the unit may therefore experience acceleration well in excess of 2 Hz/s, considered in a 100 ms interval measurement time*
- *The manufacturers of gas and steam turbines therefore consider that any maintenance consideration of RoCoF in less than 500 ms average measurement time is covered through the relevant fault ride through studies.*
- *The difficulty to study RoCoF withstand capability increases exponentially with RoCoF amplitude, while real-scale site testing is not practically possible – making more difficult the fine-tuning of turbines. Also, the current installed fleet was not manufactured with RoCoF withstand as a design criterion, which means that its capability is currently mostly unknown and shall be assessed.*

But vgbe prefers to add the sentence in a yellow background to the conclusion of EUTurbines:
Based on the information provided above, it is considered that the RoCoF requirements/expected deviations shall not be extended to more than ±1 Hz/s 500 ms for or ± 2 Hz/s 500 ms interval measurement time, also considering technology-dependent configuration of the power plant.
The RoCoF applicable for each technology shall be defined in a workshop with all stakeholders based on the principle that the general threshold is 1 Hz/sec and that exceptions for some well defined technologies are possible.

A CASE STUDY
BASED ON THE SYSTEM SPLIT OF
4 NOVEMBER 2006

UCTE: Some data of the system split of 4 November 2006

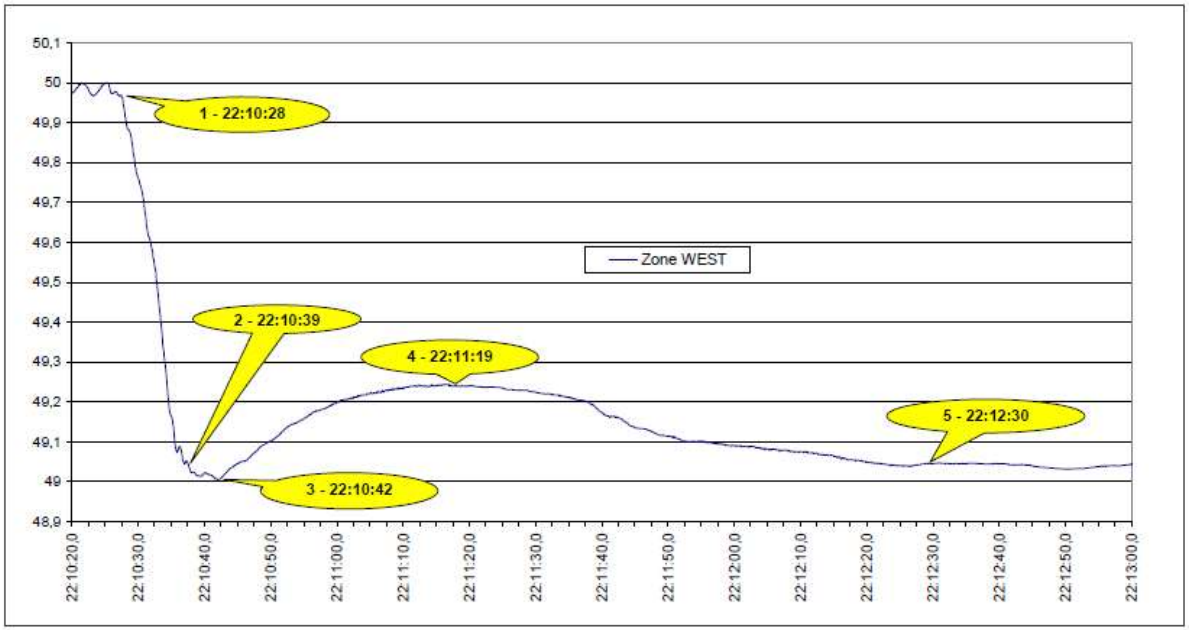


Figure10: Frequency in the Western area

① – 22:10:28, separation of the Western area from the Eastern part of UCTE
② – 22:10:39, stop of frequency decrease, mainly due to the activation of defense plans
③ – 22:10:42, beginning of frequency increase caused by additional primary reserve
④ – 22:11:19, frequency maximum at a value near 49.2 Hz
⑤ – 22:12:30 slow frequency raise to reach a normal value of 50 Hz at about 22:25

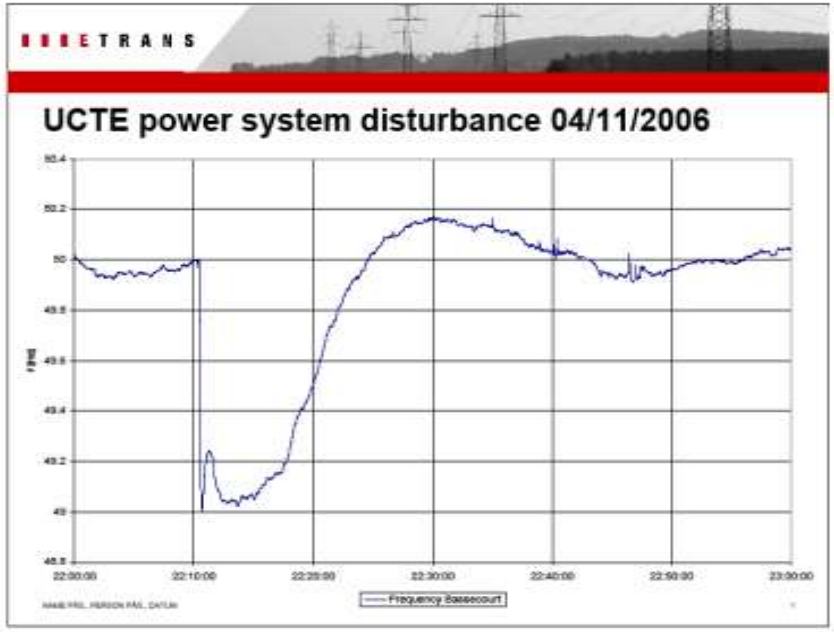
The UCTE Final Report of the System Disturbance on 4 November 2006 shows on page 29 :

Range 1 to 2

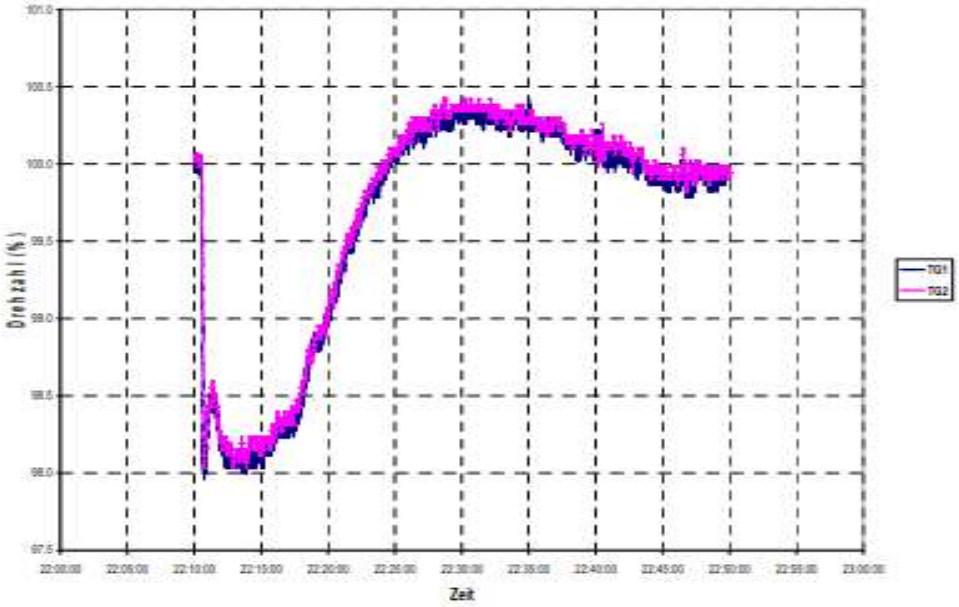
Due to the large imbalance in the Western area frequency decreased very quickly with a slope reaching up to 120-150 mHz/s. Moreover, the total imbalance was higher than the estimated primary reserve in the Western area. During this 11s time range, pumped-storage units tripped according to the defense plan but it was not high enough to face the total imbalance. Frequency still decreased.

Impact on auxiliary services of a nuclear power plant (1)

The frequency over a longer time is represented in this graph.

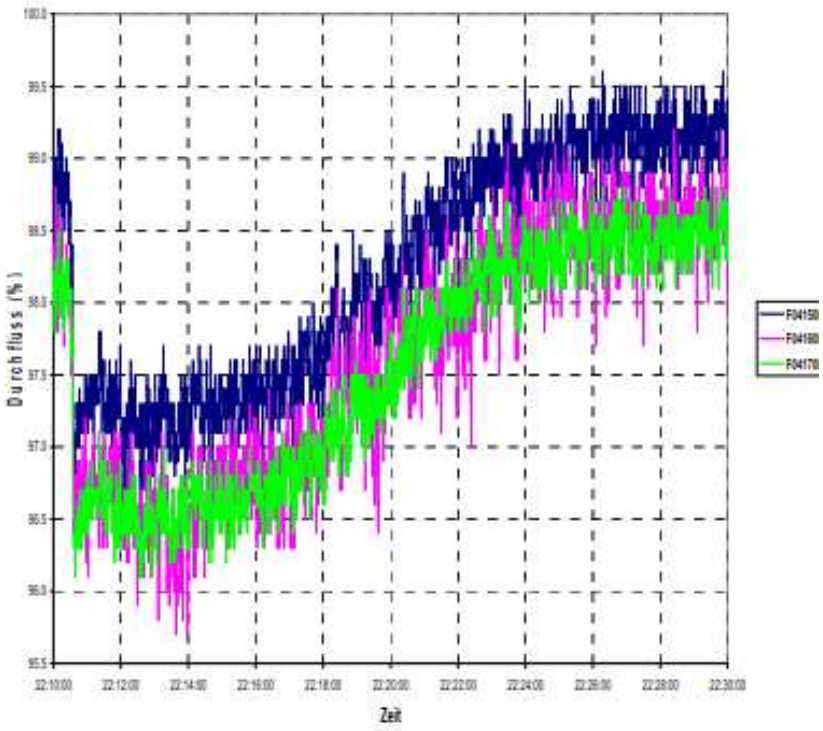


The rotational speed of the main coolant pumps of the primary circuit is represented in the graph below and it decreased to 98%.



Impact on auxiliary services of a nuclear power plant (2)

The flow in the primary coolant circuit is shown in the graph below.



This graph shows following particularities:

- The average minimal flow went to 96,5%, but the rotational speed went to 98%.
- Oscillations with a very low frequency.
- The instantaneous lowest value of the flow was 95,7%

Note :
Manufacturer's requirements impose to shut down the reactor at a flow of 93% of the rated value.

According to nuclear regulation, those requirements have to be respected during operations and such shut-down is classified as a nuclear incident and not as a grid incident.

The shut-down will last for several hours because the cause of the shut-down has to be defined and analysed.

Conclusions of this analysis of auxiliaries of a nuclear plant

Previous data are found in a old report of a unique nuclear plant.

Similar reports of events in other nuclear installations were not identified due to several reasons:

- Only at incidents with a really low frequency, such effects on main coolant pumps are noted.
- In most countries the effects of the system split of 4/11/2006 did not endanger the functioning of nuclear installations, so the related reports were classified as not important for those plants.
- It is impossible to organise a test because a high RoCoF has to initiate the event.

The low frequency event affects also other motors in a power plant.

General Conclusions

vgbe wants to formulate following topics / questions :

- Some national requirements for RoCoF are not consistent with Recital 25 of the RfG NC. Why?
- ENTSO-E indicates that experience showed that the RoCoF measuring window should be approximatively 500 msec.
  Why are other windows imposed by some national legislations?
- ENTSO-E indicates that a RoCoF above 1 Hz/sec cannot be managed by system protections.
  Why are higher thresholds imposed if they are useless in real operations?
- vgbe proposes to impose a general threshold of 1Hz/sec with a measurement window of 500 msec.
  Higher thresholds for some technologies are possible as defined in a common workshop.
- Older power plants cannot withstand a high RoCoF
- The effects of a high RoCoF on the main coolant pumps was never analysed in detail in the past.
  This problem could become a general one for all plants with a steam circuit.

A SECOND WORKSHOP ABOUT THE MITIGATION OF A HIGH ROCOF IS REQUESTED.

QUESTIONS???