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Frequency Dynamics in the Romanian Power System under Large Perturbations

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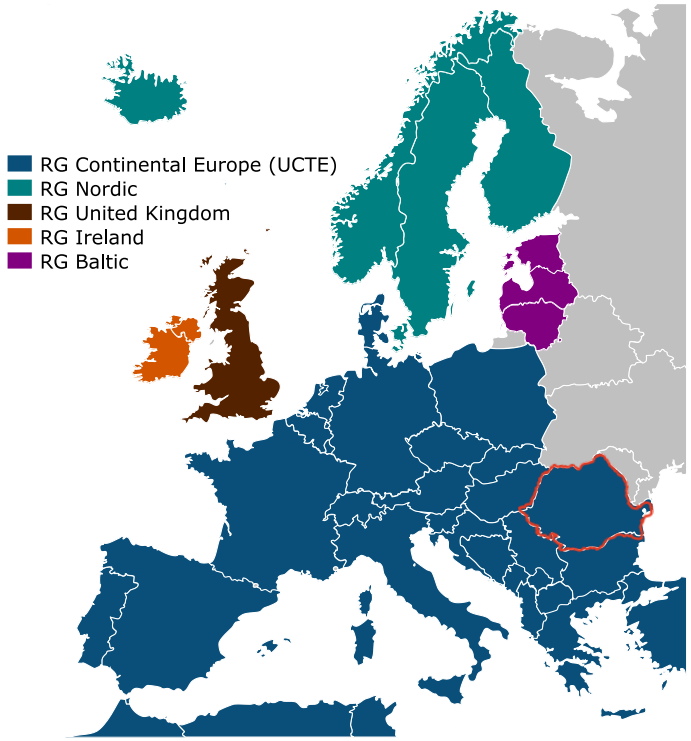
Motivation

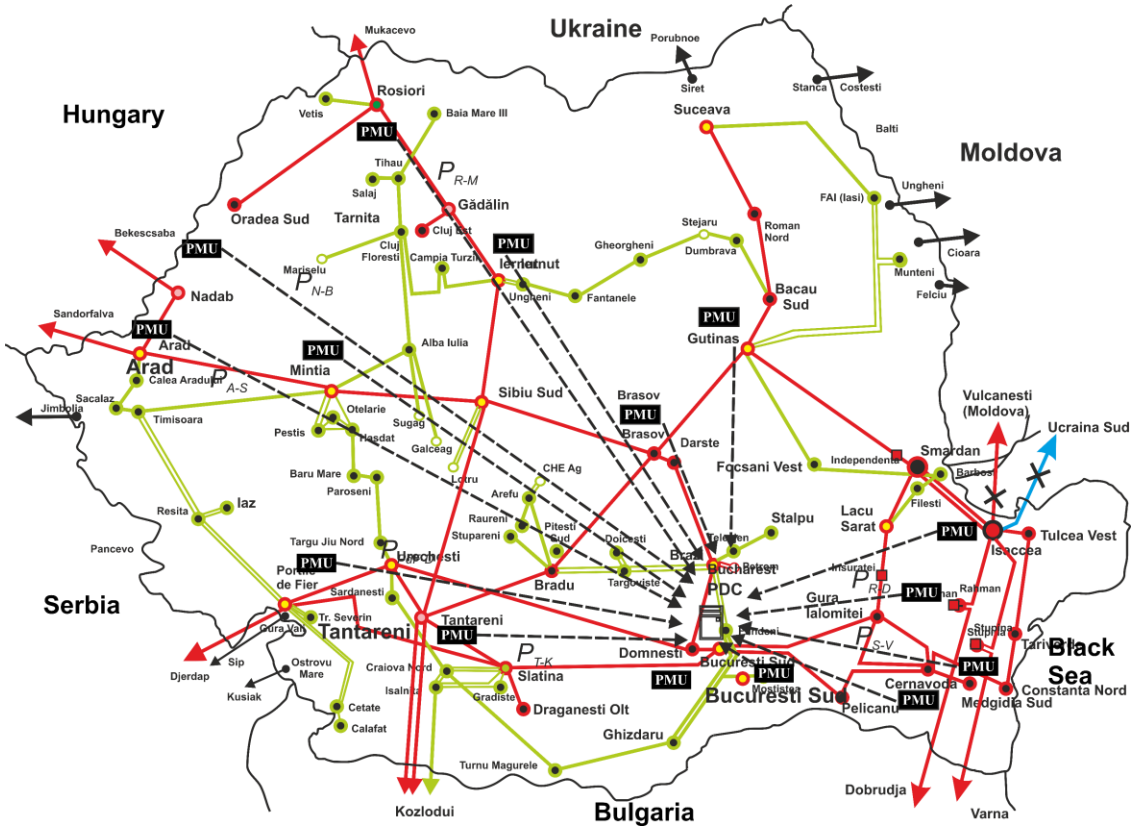
- As the coal-fired power plants are gradually dismantled, more RESs are commissioned in the effort to reduce the impact on the environment in terms of emissions, eventually to reach clean energy targets. This causes the mechanical inertia to decrease.
- The total mechanical inertia is directly related to the rate of change of frequency observable in the power system nodes.
- Our work aims to analyze the frequency data recorded by PMUs, and to corelate the information with relevant characteristics of the Romanian Transmission Network. The purpose is to understand the behavior in the actual situation of the ENTSO-E Continental Europe, and to observe the system's reaction in terms of frequency variation to sudden power unbalances.

WAMS in Romania

ENTSO-E System

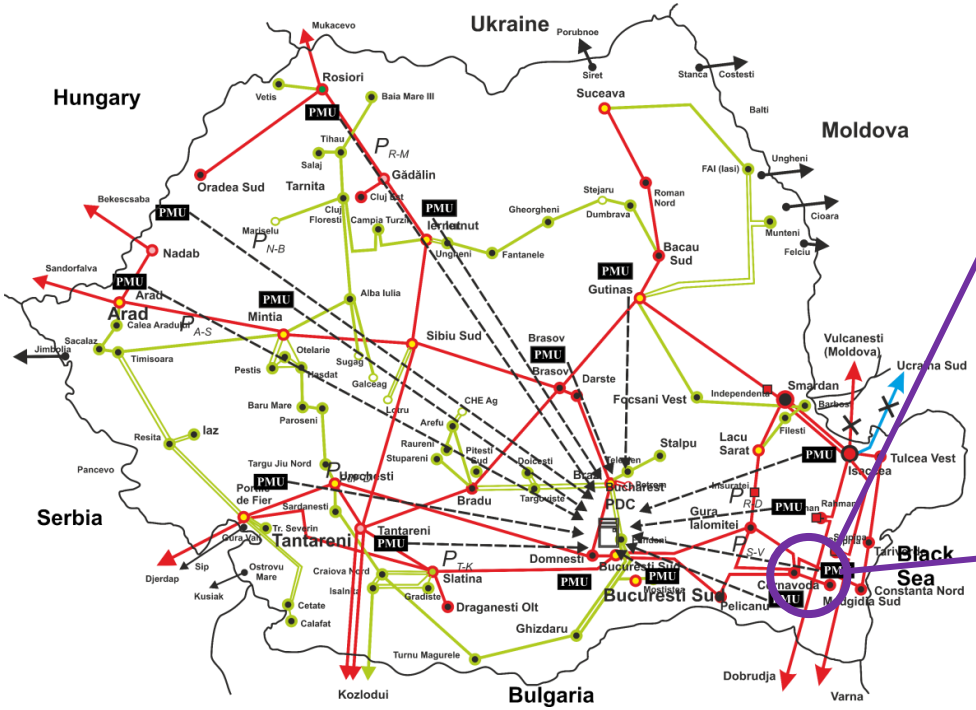


Romanian Transmission System



- 15 PMUs + 1 central PDC
- manufactured by Schweitzer Engineering Laboratories (SEL)
- Located at border buses and at the most important power plants
- Reporting rate: 25 values per second (40 ms time interval)

A. Frequency variations caused by the disconnection of large mechanical inertia



Cernavoda Nuclear Power Plant
2 x 700 MW

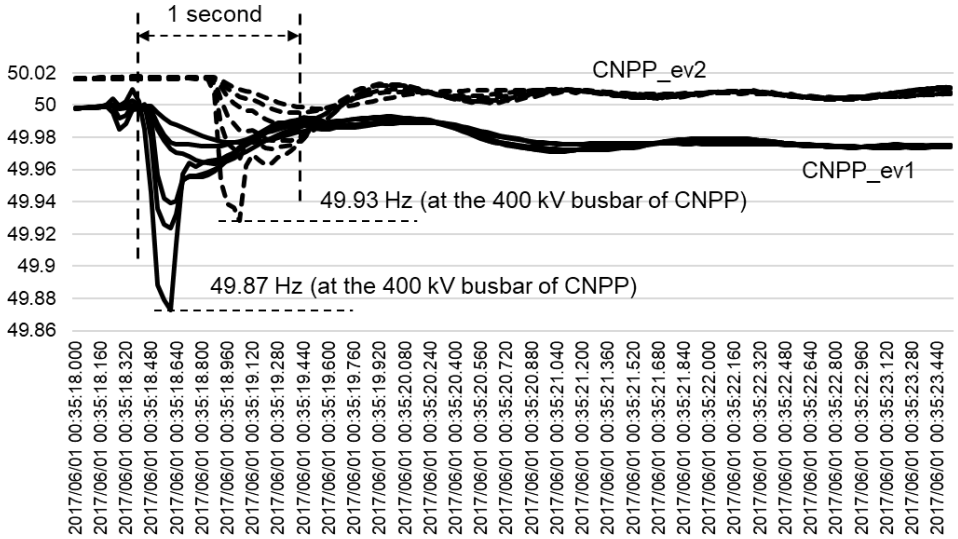
CNPP_ev1: 1st June 2017

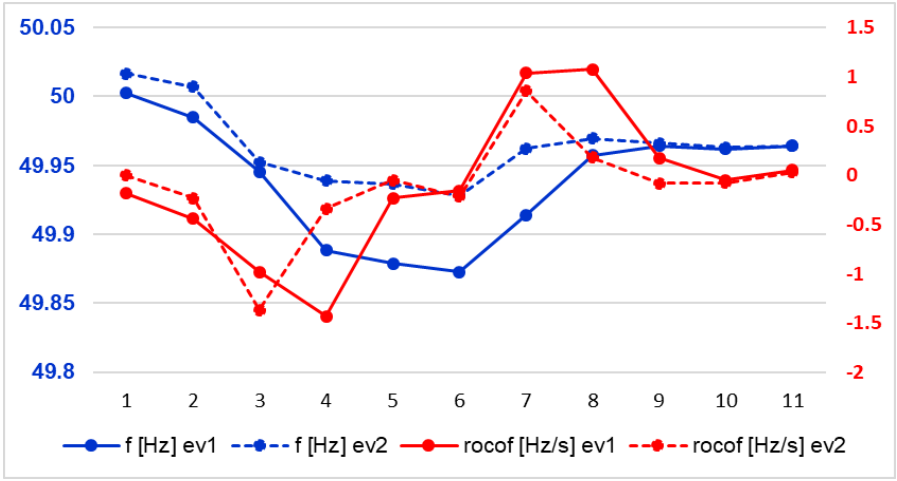
- One unit was under planned maintenance (half inertia available)
- Sudden full disconnection of the unit (no inertia remained)
- The instant of perturbation:
  - 18% wind generation
  - 17% power export

CNPP_ev2: 16 August 2018

- Both units in operation
- Sudden full disconnection of the unit
- The instant of perturbation:
  - 4.4% wind generation
  - 6% power export

A. Frequency variations caused by the disconnection of large mechanical inertia



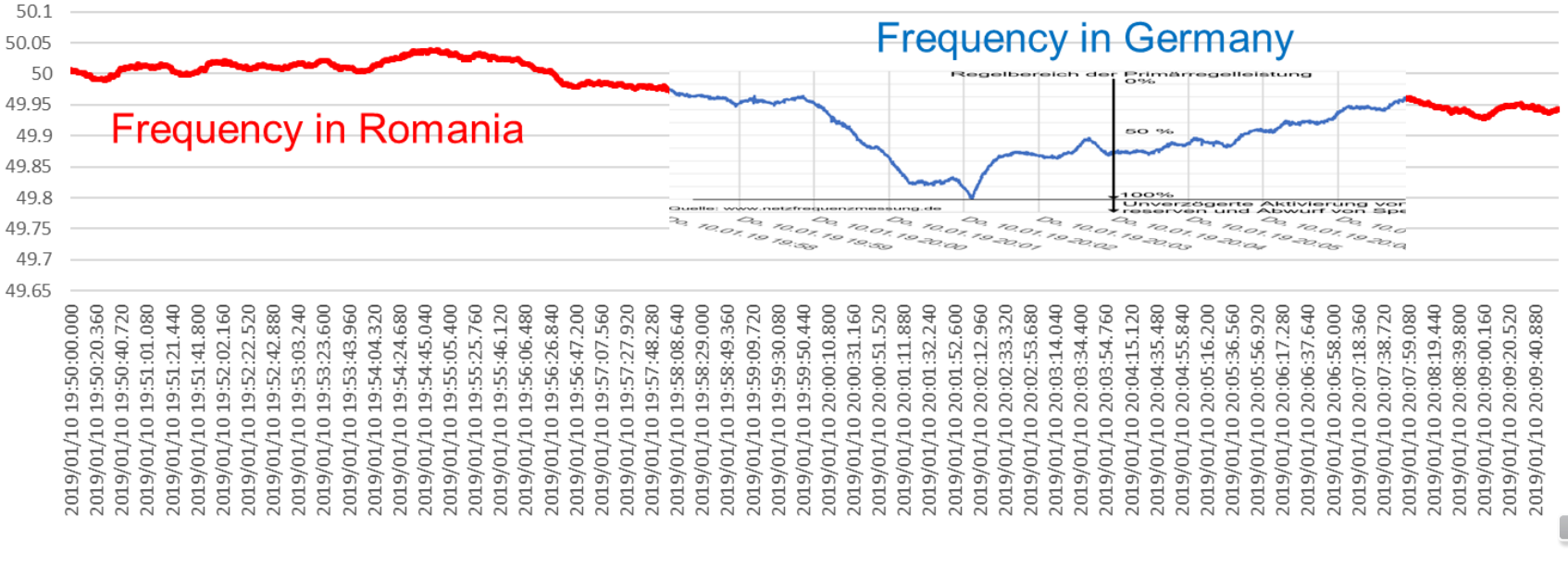


- The local mechanical inertia determines the frequency dip, which is double when both units of CNPP are disconnected
- The frequency is stabilized within 1 second, earlier than the time delay specific to the primary frequency control

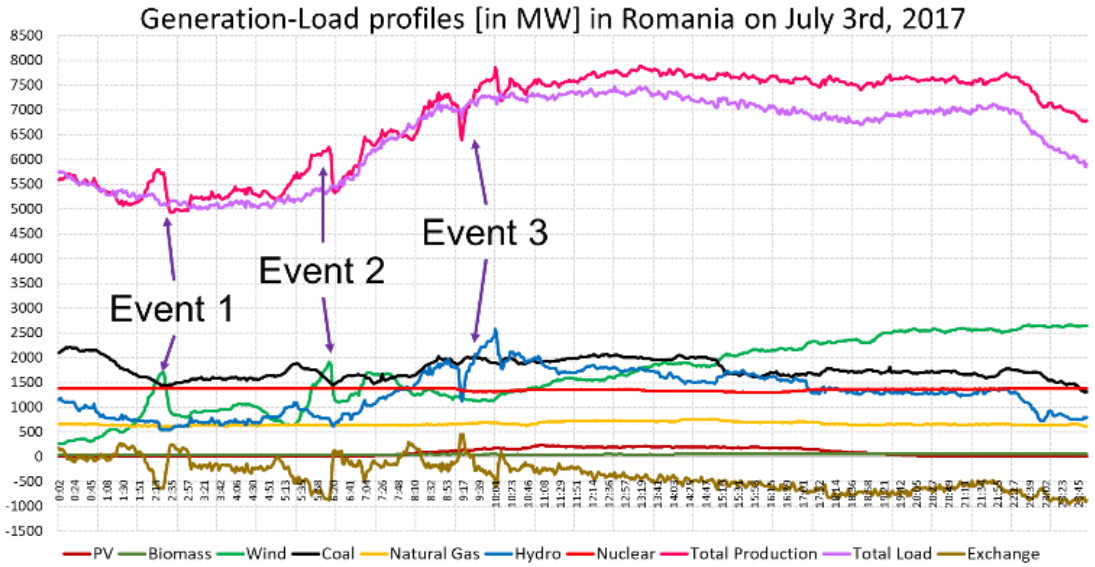
- the frequency reaches the nadir value after 5 reporting intervals (200 ms), then the frequency is stabilized after 10 reporting intervals (400 ms).
- The mechanical inertia is deployed after 2-3 reporting intervals (80-120 ms), when RoCoF starts decreasing

B. Frequency variations caused by long term unbalances

- On 10 January 2019, 21:02 CET, a new critical situation was recorded in the Continental Europe power system. The frequency dropped to 49.8 Hz for nine seconds, as compared to 49.0 Hz in 2006, during the desynchronization of the ENTSO-E power system.
- The frequency was almost identical in both Germany and Romania showing that, under the current operating conditions of the European Continental power system, with large mechanical inertia available across the system, the generators maintain synchronism with each other.

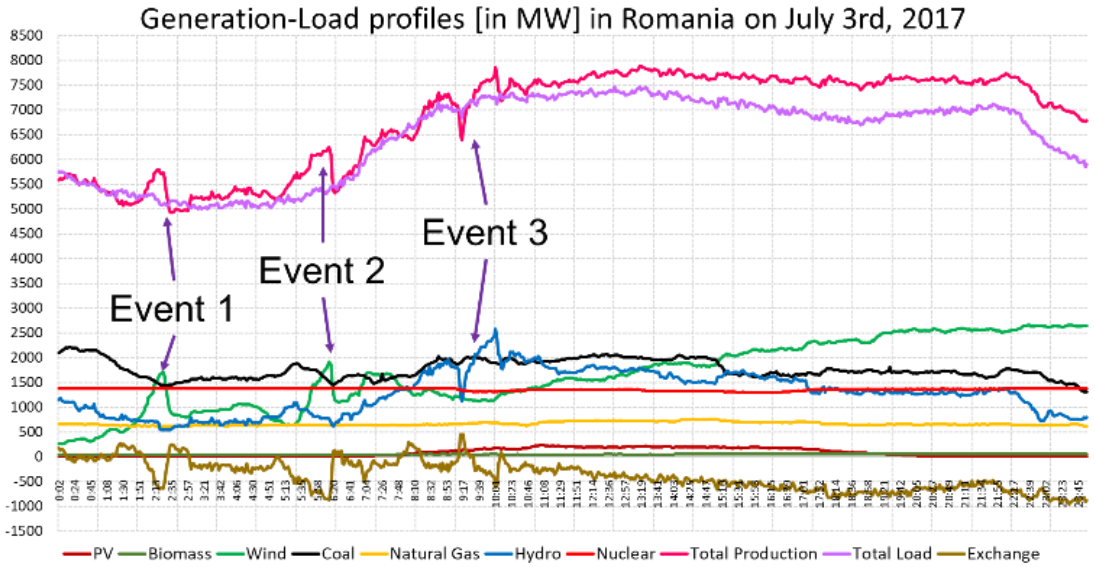


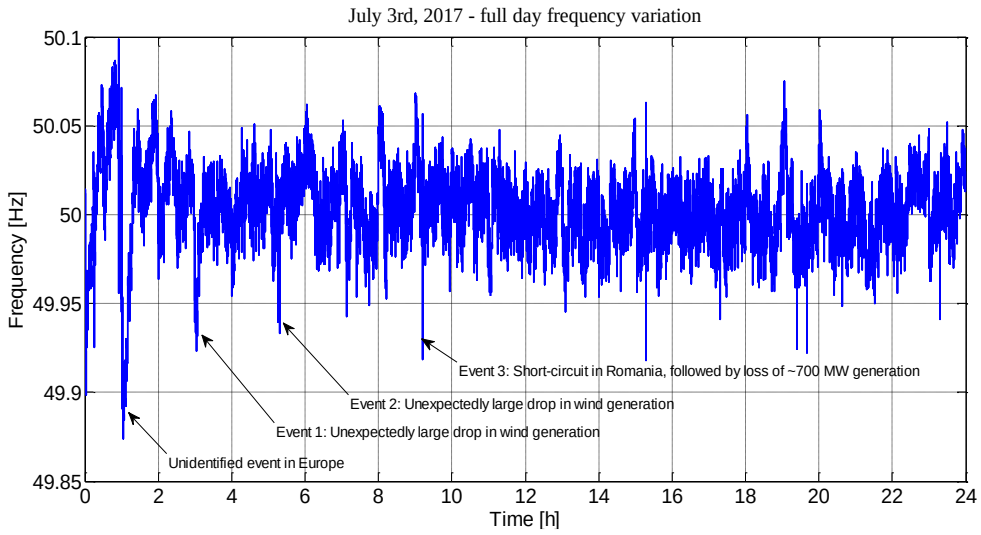
C. Analysis of frequency in Romanian on July 3rd, 2017

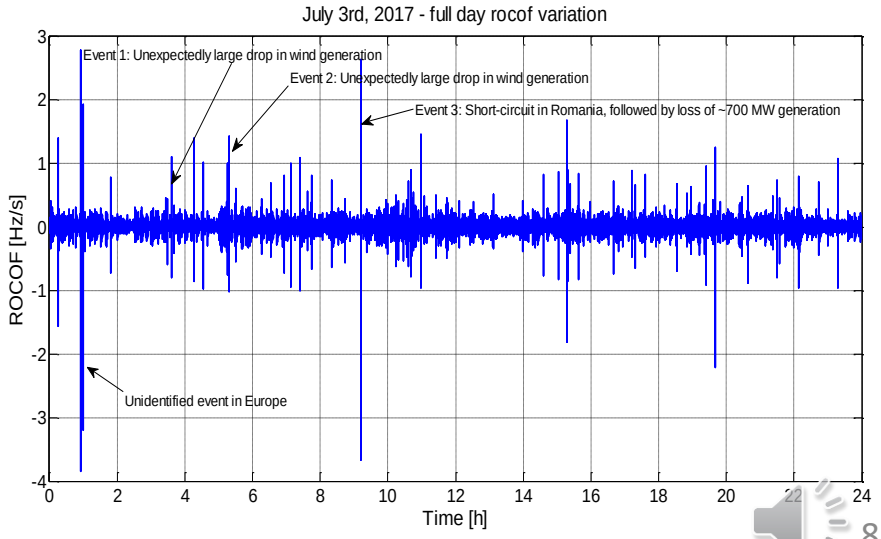


- **Event 1**: Between 1:30 AM and 2:30 AM, which means 60 minutes; the wind generation variations about 1200 MW, representing about 23% of the total load.
- **Event 2**: Between 5:30 AM and 6:20 AM, which means 50 minutes; the wind generation variations about 1300 MW, representing about 22% of the total load. An unexpected fast decrease of 800 MW was recorded within an interval of 10 minutes, between 6:13 AM and 6:23 AM.
- **Event 3**: Short-circuit on the busbar of the Iron Gates I (Portile de Fier I), a 1000 MW hydropower plant connected to RPS, followed by shutting-down the power plant and loss of about 700 MW.

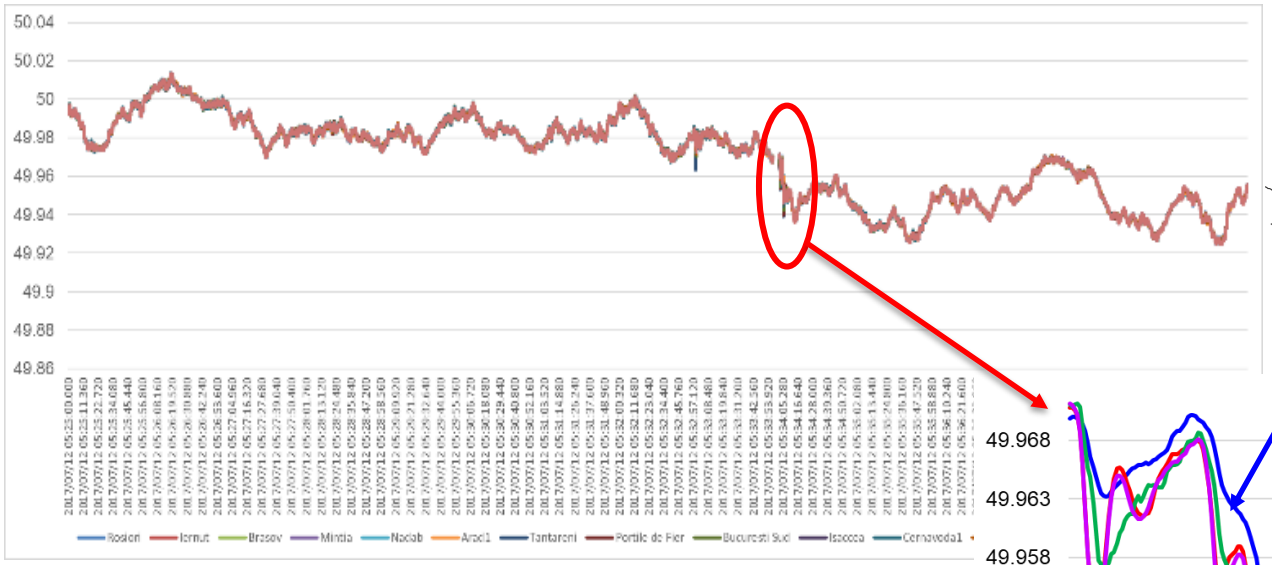
C. Analysis of frequency in Romanian on July 3rd, 2017

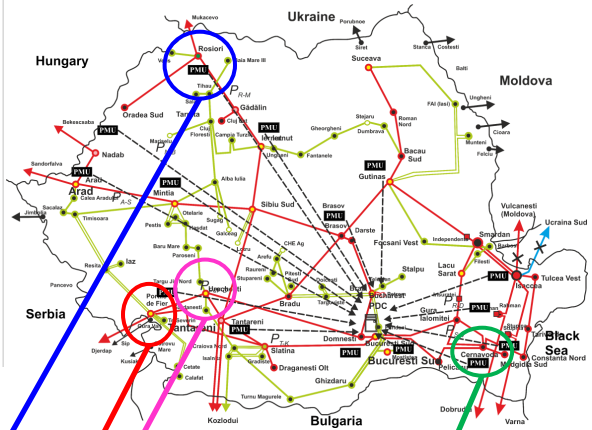


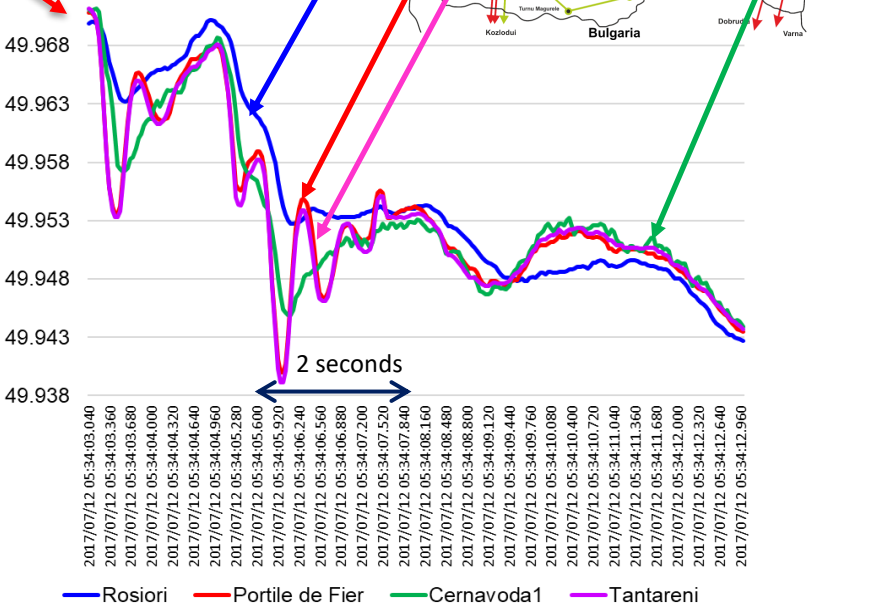




D. Analysis of frequency in case of generation loss caused by lightning







- Following severe meteorological conditions, consisting of three consecutive thunder strikes on 400 kV transmission lines, about 1000 MW in coal-fired power generation units were lost.

Conclusions

- This paper aimed at analyzing the frequency behavior in the Romanian power system upon major disturbances using PMU measurements
- The power system engineers are concerned about frequency stability in the future low-inertia power systems. This is because frequency instability can evolve very quickly, with large RoCoF values, and very low frequency values that can trigger the protection systems.
- In the case of sudden lose of the largest generation unit in Romania, together with its mechanical inertia, the lowest frequency value is reached within 120 ms. Currently most of the RoCoF algorithms recommend a time interval of 500 ms for calculating the RoCoF value, which is higher than the natural behavior.

Thank you attending!