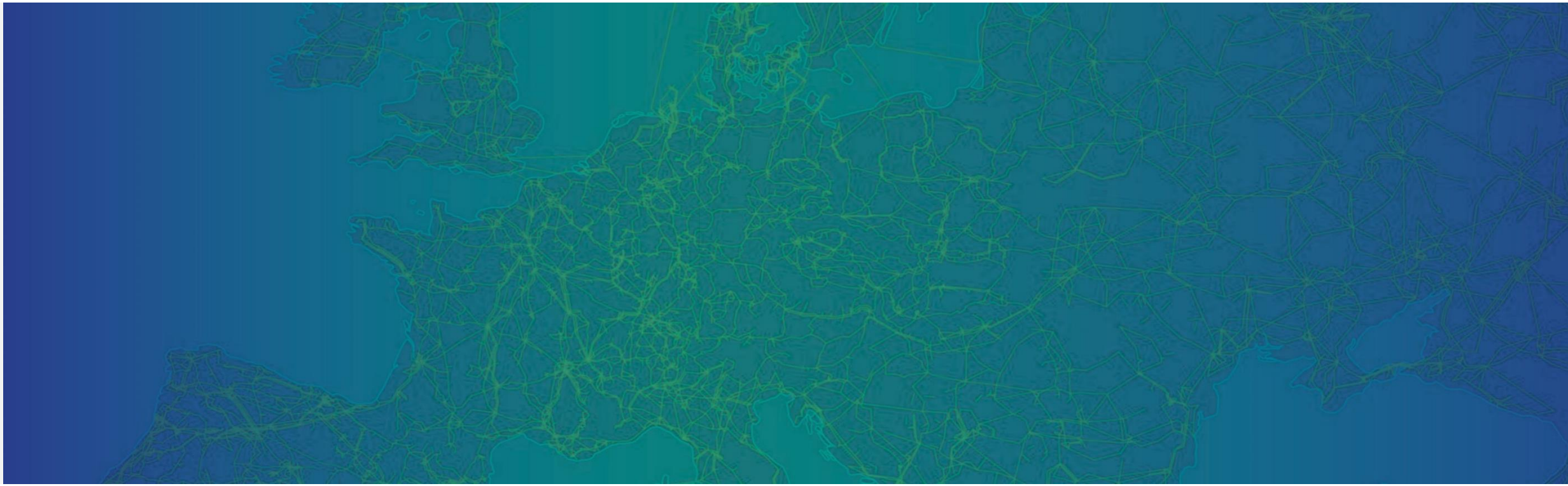
Ukraine / Moldova Synchronization with Continental Europe

ESIG Fall Technical Workshop – 26 October 2022



Albino Marques

entsoe
Reliable Sustainable Connected

Background of the cooperation with Ukraine and Moldova

- Mid-2017, TSOs of ENTSO-E Regional Group Continental Europe (RG CE) signed with Ukrenergo (Ukrainian TSO)

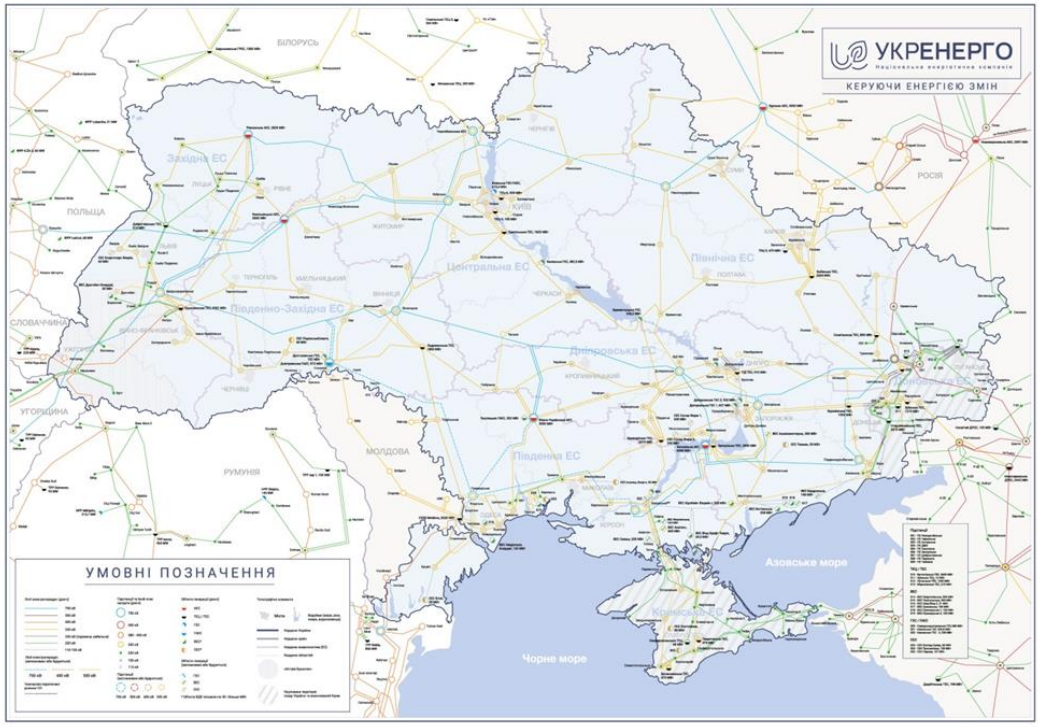
 - **“The Agreement on the Conditions of the Future Interconnection of the Power System of Ukraine/Moldova with the Power System of Continental Europe (CFI)”**

- At the same time, a similar Agreement was signed with Moldelectrica (Moldova TSO)

- **Within a six years period (until mid-2023),** these Agreements oblige Ukrenergo and Moldelectrica to:

1. Become and afterwards remain **compliant with requirements** of the Continental Europe System Operations Code (**SAFA** – Synchronous Area Framework Agreement);

The Technical Requirements were defined in the “Catalogues of Measures” (annex of the agreement)



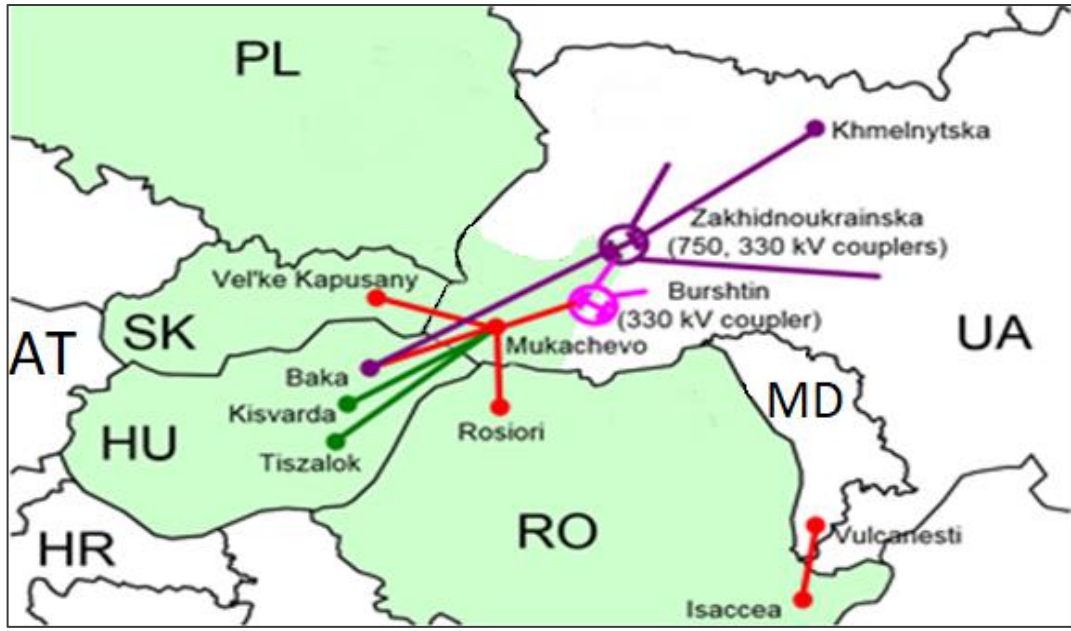
Background of the cooperation with Ukraine and Moldova

2. Perform **steady-state and dynamic studies** to confirm the feasibility of the interconnection (the studies have been executed – final report issued in November 2021);

3. Fulfil the **dynamic stability requirements** (additional damping measures needed – by intervening in control loops of nuclear units or/and by installing STATCOMS

4. Perform **island operation** (planned for 2022) – to demonstrate the functioning of load-frequency control

5. Perform **trial synchronous operation** (planned in **Q2/2023** – no return when started) damping measures must be implemented before



- Reminder: **Burshtyn Island** (small occidental part of Ukraine was synchronously connected to CE (since 1 July 2002);
- Project Group Ukraine/Moldova (PG UA/MD) below ENTSOE/RGCE (Regional Group Continental Europe) supervises and RG CE takes all related decisions

Emergency synchronization facts

24 February 2022

Russia launches a military invasion of Ukraine

24-26 February 2022

Ukrenergo/Moldelectrica perform the scheduled winter isolation test by operating their system in island mode.
Tests showed good results.

26 February 2022

Ministry of Energy of Ukraine issued a regulation to refuse reintegration into power systems of Russia and Belarus

27 February 2022

Ukrenergo requests RGCE to allow for emergency synchronisation with Continental Europe power system

28 February 2022

EU Energy Ministers council supports the immediate emergency synchronisation of the Ukrainian/Moldovan power system with Continental Europe

28 February 2022

Moldelectrica sends corresponding request

1 March 2022

RGCE establishes a dedicated Task Force "Emergency Synchronization"

11 March 2022

RG CE approved **by unanimity** the emergency synchronisation of Ukrenergo/ Moldelectrica power system with Continental Europe

- 17 days after request
- 1 year before planned

16 March 2022

Emergency Synchronisation is successfully completed.

No commercial exchanges allowed, to limit stability risks

Dedicated task force of experts

- ENTSOE/RGCE decided to put in place a **dedicated Task Force of experts** to analyze the risks, and evaluate minimum required measures in order to make possible an emergency synchronization of Ukraine/Moldova power systems to Continental Europe

- The Task Force has 4 parallel workstreams

- A strong involvement from relevant experts was key for the success of this Task Force
  - **more than 40 people**

Main Risks of Emergency Synchronization analyzed by the Task Force

Instability and system security risks

- Comprehensive 24/7 monitoring to detect oscillations (PMW data from Ukrainian system shared with ENTSOE systems)
- Network cross border transfer capacities **set to ZERO**

Reserve depletion risk

- Ukrenergo has demonstrated during isolated test excellence in balancing their system
- There was a lot of available generation capacity in UA/MD

Cyber-security risk

- Design and implementation of a specific ad-hoc solution to exchange real-time data with Ukrenergo, using private communication links - PCN
- Ukrenergo to send data to European Awareness System (EAS)

Legal & regulatory risks

- Significant risks and potential liability exposure for the TSOs if Ukrenergo is not able to pay its bills in case of strong unintended deviations).

Conclusion : the identified risks can be mitigated

Lessons learned after 2 months of trial synchronous operation

- Ukrenergo **balances very well its system**
- **Mutual real-time observability** from the adjacent TSO networks installed and improving
- **Inter-area oscillations** are observed but remain under control
  - The oscillations are generally properly damped, but are sometimes close to the limits. No preventive counter-measure is required.
  - Starting with NTC(network transfer capacity) = 0 was the right decision
  - Implementation of damping measures in Ukraine is still necessary in view of future commercial exchanges
- Interface is relatively weak
  - Important loop flows are observed Romania-Ukraine-Hungary

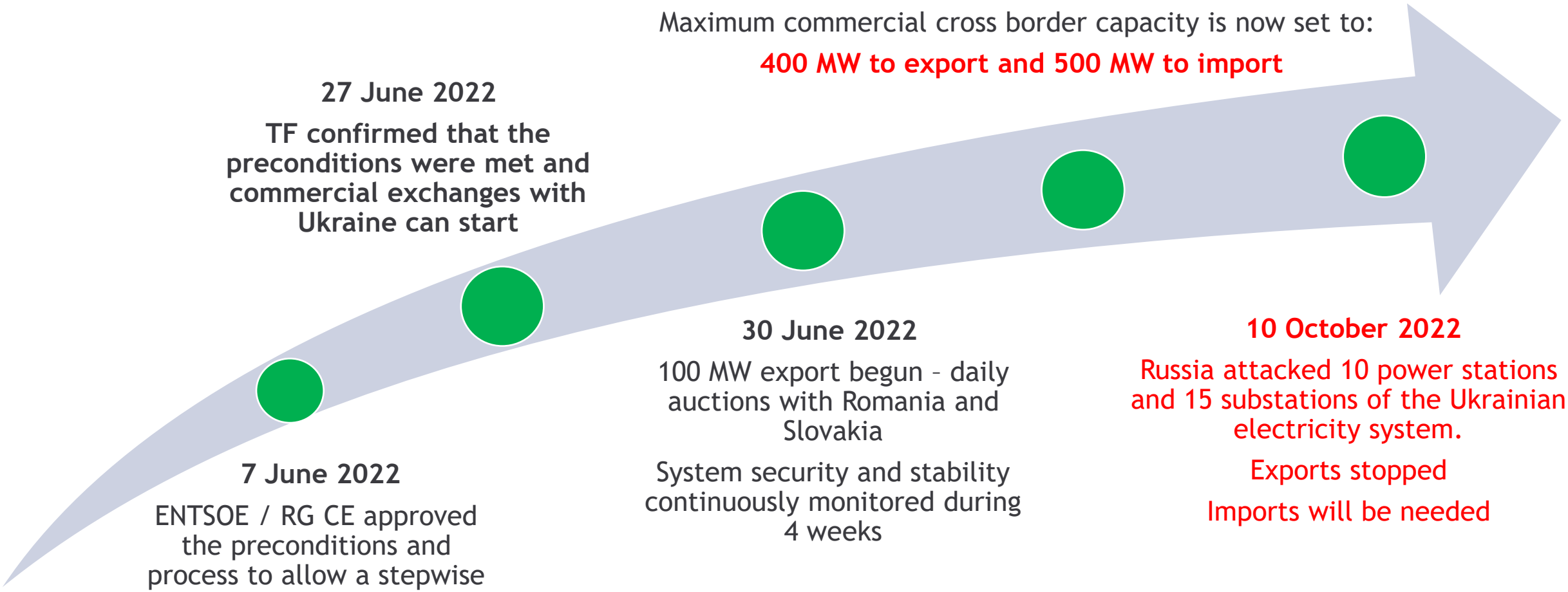
Preparing for increased commercial exchanges

- Since 30th March, Ukraine begun exporting to Poland via a radial line (no impact on oscillations)

- Continental Europe TSOs (RGCE) assessment - how and when **to allow more exports from Ukraine, while maintaining the security and stability of the interconnected power system**

  - Goal was to allow a gradual (step by step) increase of exchange capacity via the interconnections
  - Several preconditions were established regarding :
    - **Damping of oscillations**
    - **Operational security**
    - **Scheduling and coordinated operations**
    - **Imbalance settlement**
    - **Incident management**
  - Reduction of NTC was possible at any time, if the security of the system was endangered

Commercial exchanges timeline



7 June 2022

ENTSOE / RG CE approved the preconditions and process to allow a stepwise increase of the commercial exchanges

27 June 2022

TF confirmed that the preconditions were met and commercial exchanges with Ukraine can start

30 June 2022

100 MW export begun – daily auctions with Romania and Slovakia

System security and stability continuously monitored during 4 weeks

Several meetings during July, August and September

Step by step increase was approved by all RGCE TSOs

Maximum commercial cross border capacity is now set to:

400 MW to export and 500 MW to import

10 October 2022

Russia attacked 10 power stations and 15 substations of the Ukrainian electricity system.

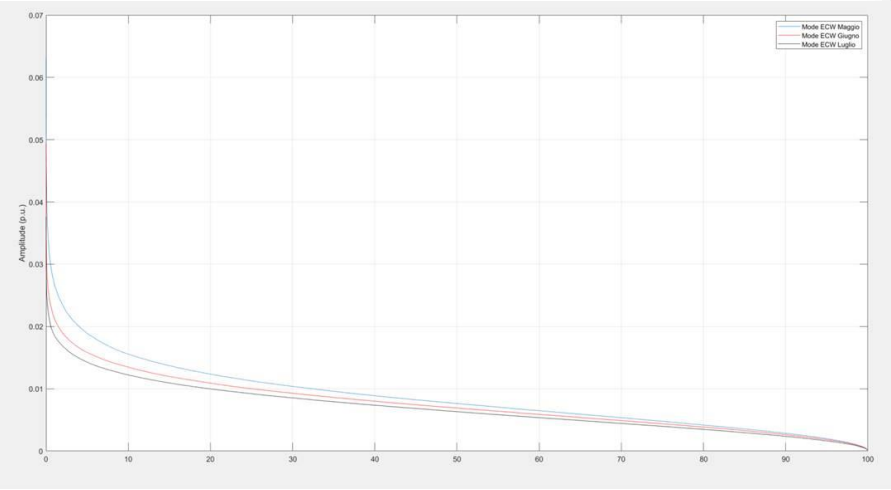
Exports stopped

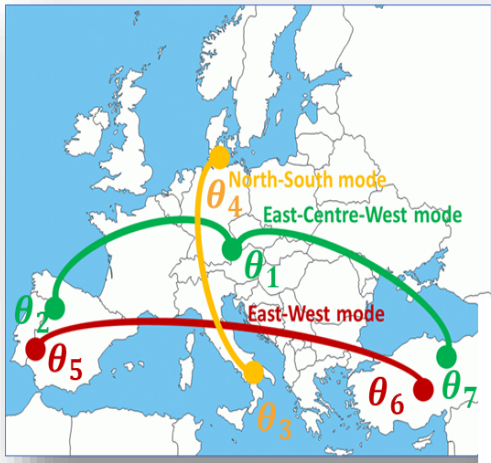
Imports will be needed

Stability observations summary

Dedicated expert team to observe and post process PMU data from several network nodes across Europe from Ukraine to Portugal

ECW amplitude duration curves





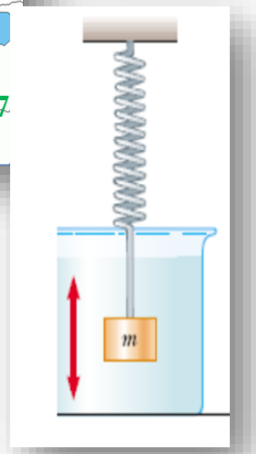
0.3 Hz

0.2 Hz

0.15 Hz

$P \propto \sin(\Delta\theta)$ ➡ $K \propto \frac{\cos(\Delta\theta)}{X}$ Dynamic "spring" effect

$\Delta\theta \propto$ Large power flows between CE "centre" and "periphery"



inertia — "spring effect"

$$m \cdot \frac{d^2x}{dt^2} + b \cdot \frac{dx}{dt} + k \cdot x \Rightarrow 2 \cdot H \cdot \frac{d^2x}{dt^2} + b \cdot \frac{dx}{dt} + K \cdot x$$

damping contribution

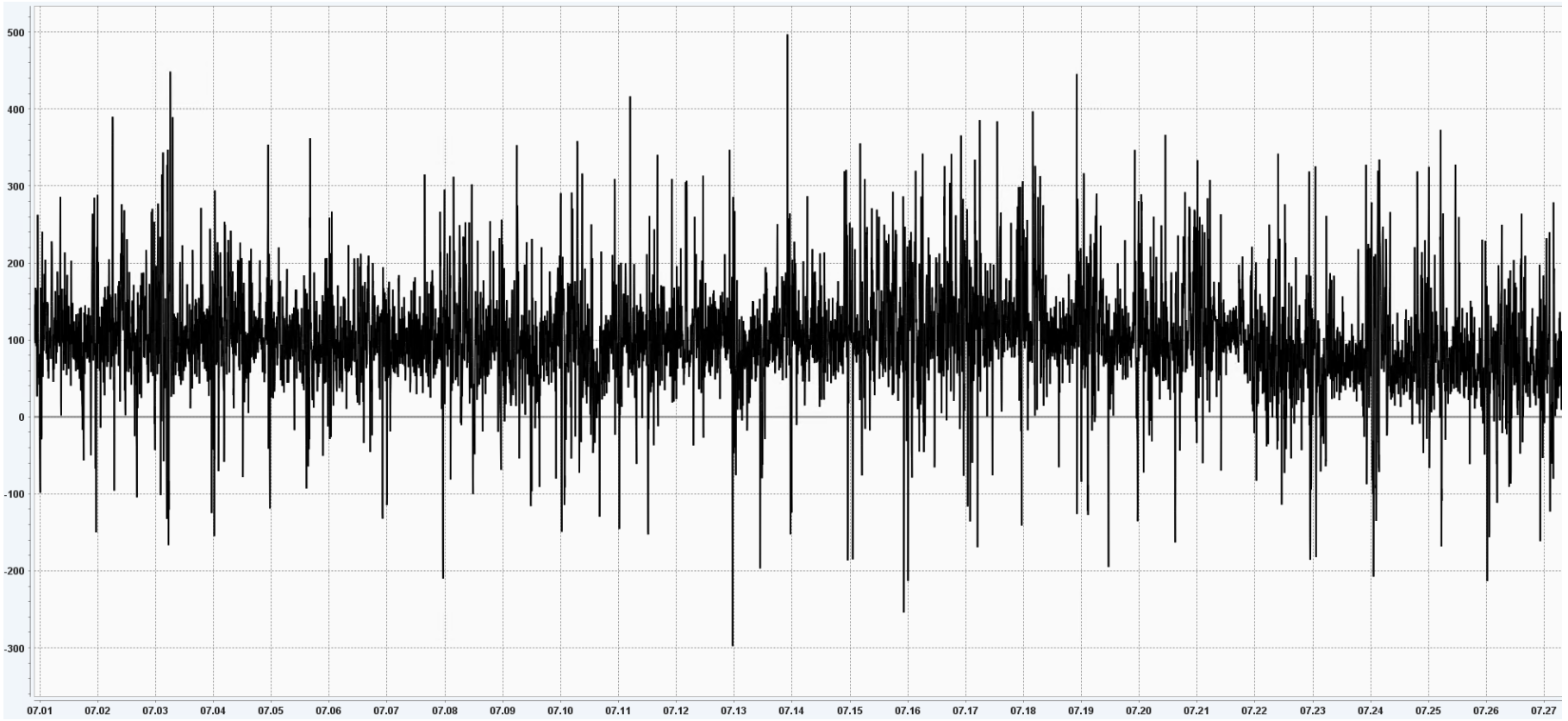
"b" damping contribution depends on: loads, angle spread, operating point and reactance seen by generators

Power absorbed by loads depends by voltage P$\propto V^2$

The oscillatory stability behaviour is in general good
Counter measures applied in some cases when poor damping was observed

The quality of balancing

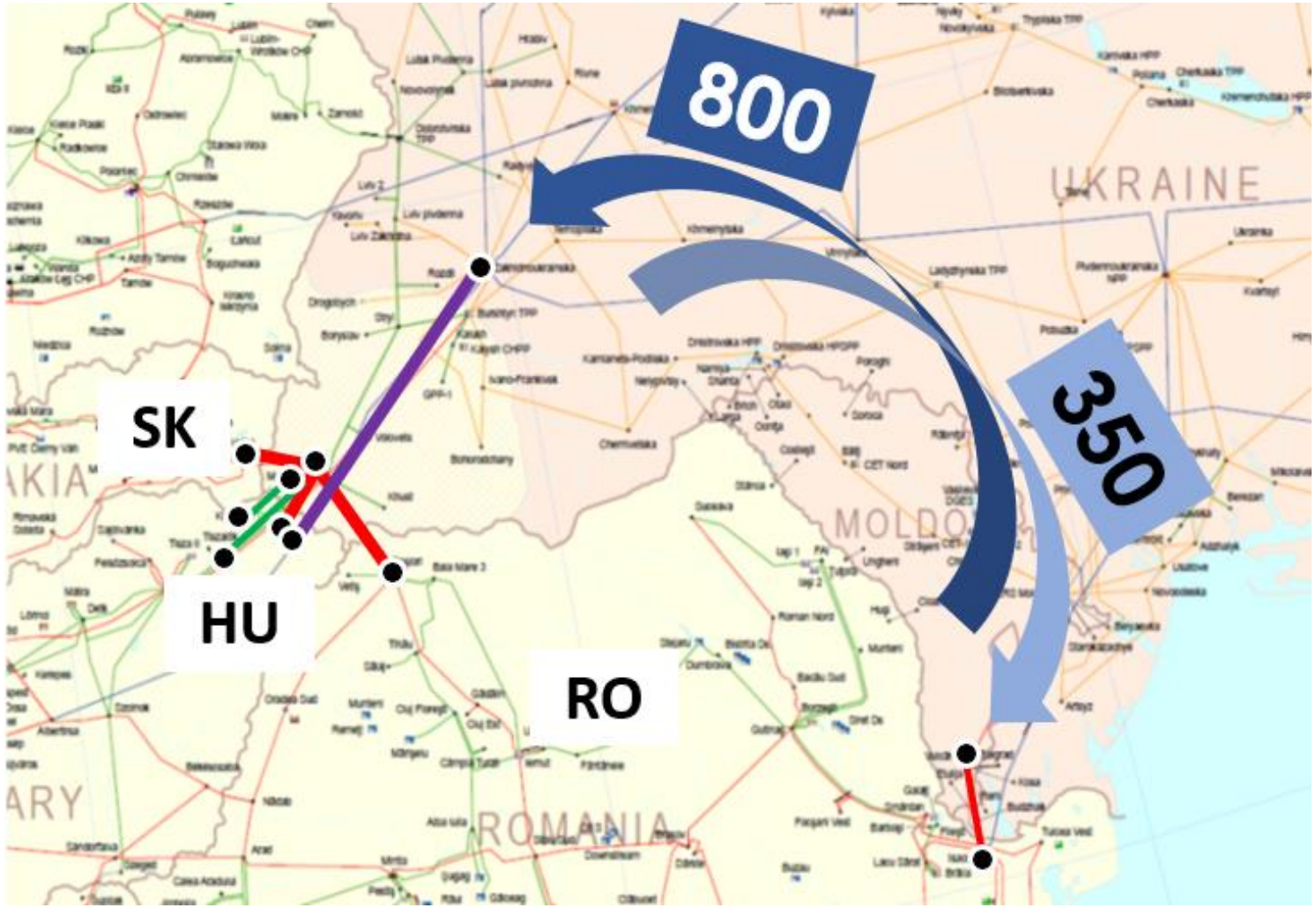
Between 1st & 27th July, the net position of UA+MD control block (100 MW exporting) was maintained (figure below)
Peak deviation 450 MW with fast recovery. Typical deviations between 100 MW and 200 MW on daily basis.



The overall quality of balancing is adequate.

Physical flow on the borders

Volatile transit flow through UA+MD has been experienced since the synchronous connection of UA+MD to CE.
The transit flow has been changing between about 800 MW (towards NW) and 350 MW in opposite direction (towards SE).



Operation Experience

- More than half a year successful interconnected operation
- Stable operation during outages
- Well-damped behaviour during transients
- Satisfactory damping with respect to different inter-area modes
- Application of remedial actions in the case of danger of overloading of several interface interconnections
- Detailed approach for mitigation of long-lasting poorly damped inter-area oscillations
- Permanent monitoring and adaption of significant parameters within a common transparent dialogue
- Stepwise approach by combining model calculation with measurements analysis

Project success factors

- Setup of **dedicated ENTSO-E working groups** for preparing system enlargement/extension
- **Setup of Catalogue of Measures**
- Preparation of **steady-state and dynamic model studies** with model validation by performing of dedicated tests
- **Investments in Ukraine** to reinforce the equipment and system structure including power plant control principle
- Ensuring of enough damping with respect to poorly damped inter-area oscillations
- **Preparation of coordinated system interconnection scheme, schedule for interconnection**
- **Emergency operation coordination plans**
- **Preparation and realisation of dedicated system island mode tests**
- **Harmonisation of interface connection protection settings**
- **Harmonisation of system defence plans**
- Ensuring of data exchange – for on-line and offline data (schedules, contingency analysis data sets, SCADA data, WAMs data, metering data)

Conclusions

- The emergency synchronization project is a success thanks to :
  - **Spirit of solidarity in the sector** to support Ukraine and Moldova
  - Strong **political and regulatory support**, from European Commission, Member states, European and National Regulatory agencies
  - Fully **dedicated and highly skillful experts** to analyze the risks and develop solutions, also relying on the preparatory work performed since 2017
  - Very **lean and agile project approach**
  - The work continues…Ukrenergo is already an observer member of ENTSOE

Our values define who we are, what we stand for and how we behave.
We all play a part in bringing them to life.

EXCELLENCE

We deliver to the highest standards. We provide an environment in which people can develop to their full potential.

TRUST

We trust each other, we are transparent and we empower people. We respect diversity.

INTEGRITY

We act in the interest of ENTSO-E

TEAM

We care about people. We work transversal and we support each other. We celebrate success.

FUTURE THINKING

We are a learning organisation. We explore new paths and solutions.

We are ENTSO-E