ESIG Special Session: An introduction to the Global Power System Transformation Consortium

March 27, 2023

GLOBAL PST CONSORTIUM

Global Power System Transformation Consortium: Brief overview

Karin Wadsack, Ph.D.

27 March 2023

ESIG Spring Workshop

GLOBAL PST CONSORTIUM

nationalgridESO

NREL Transforming ENERGY

IEEE Advancing Technology for Humanity

VTT

AEMO AUSTRALIAN ENERGY MARKET OPERATOR

CSIRO

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Imperial College London

EirGrid GROUP

DTU

Fraunhofer CINES

olade Organización Latinoamericana de Energía

ercot

ESIG ENERGY SYSTEMS INTEGRATION GROUP

California ISO

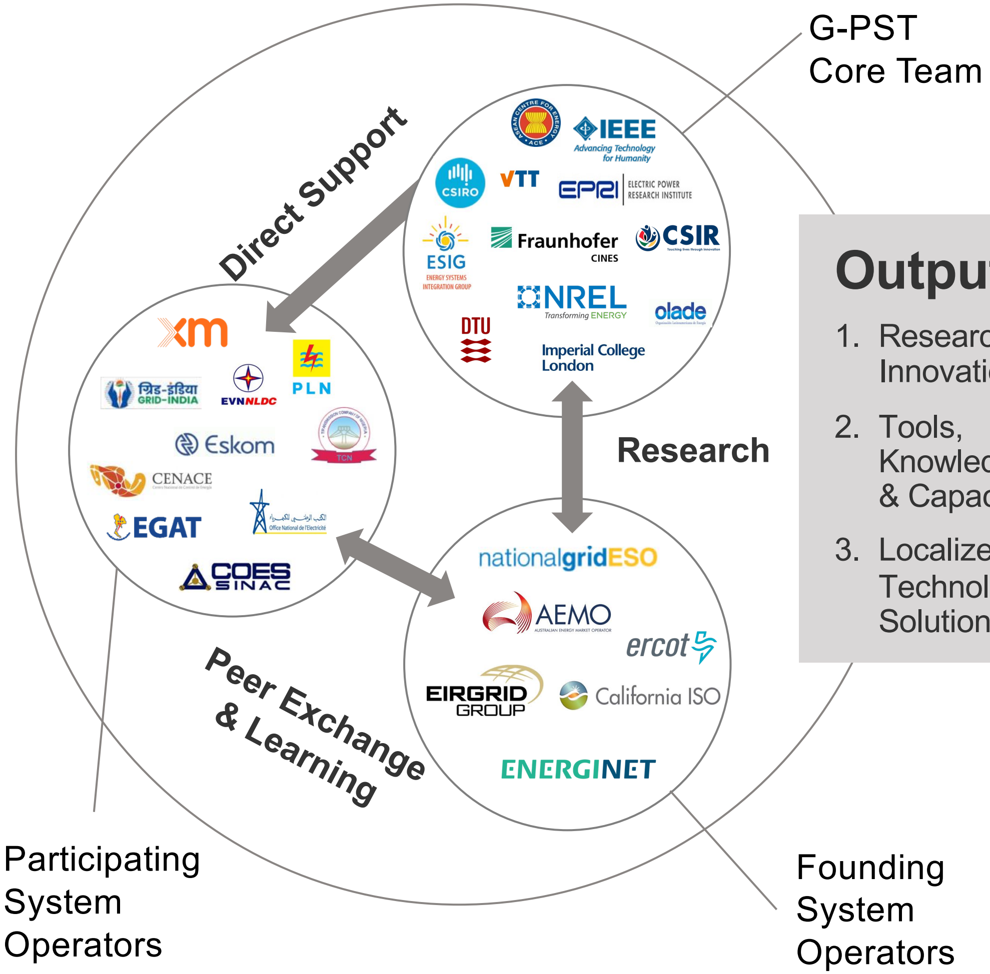
CSIR Touching lives through innovation

ENERGINET

ASEAN CENTRE FOR ENERGY ACE

Theory of Change for the G-PST Consortium

G-PST Consortium



Ecosystem of Collaborators

Outputs

1. Research Innovations
2. Tools, Knowledge & Capacity
3. Localized Technology Solutions

Outcomes

1. Grid Modernization
2. Ambitious Plans and Visions
3. Confidence to Realize Low-Carbon Solutions

Impacts

1. Significant private investment in advanced power systems
2. Reduced energy and delivery costs for consumers
3. Significant emissions reductions for the power sector
4. Increased system reliability and resiliency
5. Jobs and economic development

Advancing Action in Five Key Areas

1. System Operator Research & Peer Learning

ESIG

Perform cutting edge applied research to create novel system operator solutions and globally disseminate and infuse new insights through peer learning

2. System Operator Technical Assistance

NREL Transforming ENERGY

Provide implementation support to scale established best practice engineering and operational solutions

3. Foundational Workforce Development

Imperial College London

Build the inclusive and diverse workforce of tomorrow through enhanced university curriculum and technical upskilling for utility and system operator staff

4. Localized Technology Adoption Support

IEEE Advancing Technology for Humanity

Adapt modern power system technologies to individual country contexts through testing programs and standards development activities

5. Open Data and Tools

VTT
NREL Transforming ENERGY

Support rigorous planning, operational analysis and enhanced real-time system monitoring through open data and tools

CORE TEAM – All Core Team members contribute to all activity pillars

olade · NREL · EPRI · ESIG · IEEE · DTU · Fraunhofer · CSIR · Imperial College London · CSIRO · VTT

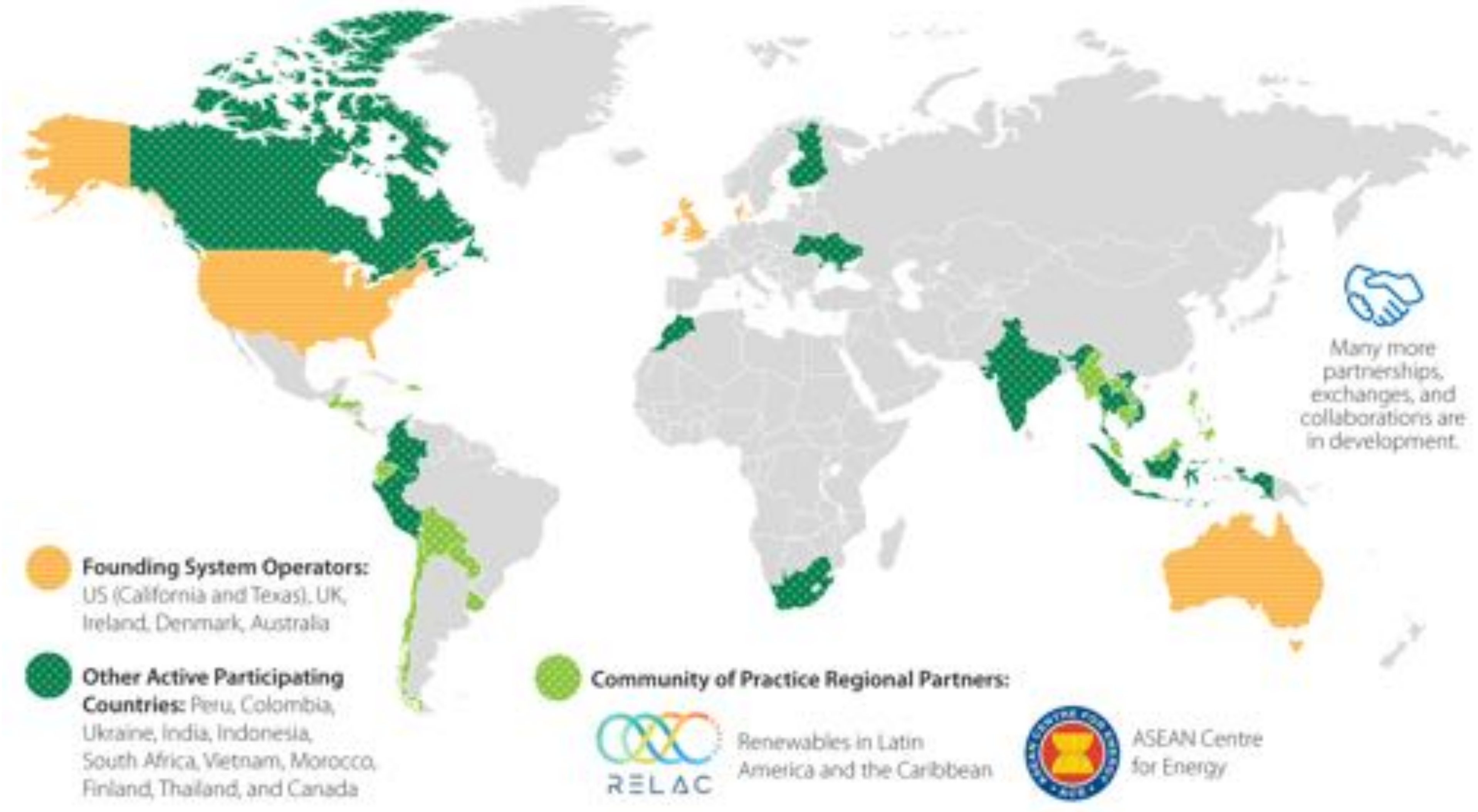
REGIONAL LEADS – Coordinate regional peer learning networks and country-level technical assistance delivery efforts for Africa, Asia, and Latin America and the Caribbean

ASEAN Centre for Energy · olade · CSIR · RELAC

INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.

NREL Transforming ENERGY

Global Participation



2021-2022 Accomplishments Highlights

- Global Research Agenda and Teaching Agenda in execution
- Ten technology collaborations among FSOs for operational changes, model demos
- Grid-forming technology council launched; includes top electrical equipment suppliers (Hitachi Energy, Siemens Energy and GE). First draft of phased GFM testing program prepared. Collaboration underway with ENTSO-E
- Oscillation source detection tool deployed in India's Southern Load Despatch Centre; inertia monitoring toolkit implementation underway with South Africa's ESKOM and Vietnam's NLDC; control room modernization roadmap published with Peru's COES
- Internships at NREL, EPRI; PLN (Indonesia) and CAISO (California) fellowships
- Launch of five free course modules; accessed by more than 170 users
- Power system standards implementation pilots in Panama and India
- Open-source tools portal; benchmarking activities, 148 people from 111 organizations

Scan the QR to learn more about G-PST's impact so far.

CEO Target: Operate One 100% IBR Transmission System by 2025 and Enable All Countries to do so by 2035

Enablers to Achieve FSO Goals

- ✓ Define and adopt new system needs & services framework
- ✓ Advanced techniques to define and ensure resource, energy, and flexibility adequacy
- ✓ Deployment of advanced technology capabilities (e.g., GFM) to meet grid needs & provide services
- ✓ Refined stability tools, models, methods & metrics
- ✓ Advanced operational capabilities (e.g. control room of the future)
- ✓ Distributed energy resources architecture, operation and impact

2025 Impacts of Top Projects

- ✓ Three FSOs adopt: system services framework, GFM standards, stability tools, control room of future plans, resource adequacy metrics
- ✓ Ten developing country system operators implementing holistic transformation, including workforce development, tools & standards
- ✓ All 90+ curriculum modules in use
- ✓ 12+ new standards in development
- ✓ Open-source tools available across planning & operations workflow

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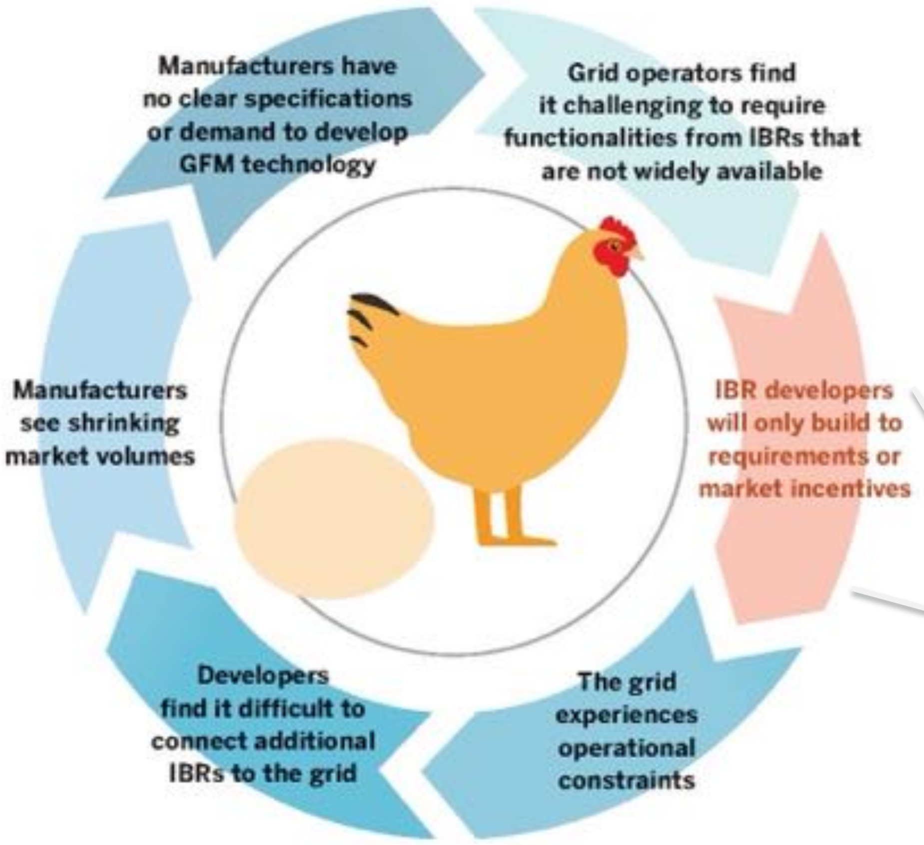
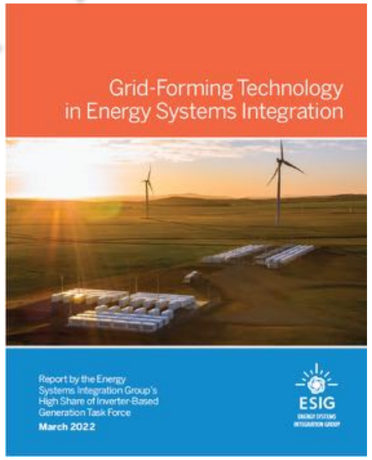
Grid Forming Technology Council (GFMTC)

March 27th 2023

Jason MacDowell | ESIG

The Circular Problem of Requirements and Deployment of Advanced IBR Controls





1. Which comes first, the requirement for a capability or the capability itself?
2. How do grid operators know what performance or capability is possible from new equipment? What could they require?
3. How can they go about evaluating the costs and benefits of having such equipment on the grid?
4. What drives manufacturers to invest in new technology without it being mandated or otherwise incentivized by the market?

https://www.esig.energy/grid-forming-technology-in-energy-systems-integration/

GFM TECHNOLOGY COUNCIL INITIATIVES

PURPOSE - Break the chicken-egg cycle through deployment and commercialization of GFM technology by:

a) identifying GFM features/requirements by system operators
b) supporting technology demonstrations and deploying GFM resources from OEMs
c) GFM resource procurement by developers
d) Standardization, codes and interconnection requirements

METHOD - Cross-pillar I, II and IV collaboration with FSOs, developers, OEMs, software developers, standardizing institutions and other stakeholders

CONFIRMED & POSSIBLE PARTICIPANTS:

Leadership

- ✓ Sten Arendt Stoltze, SVP Orsted (Chair)
- ✓ Jason MacDowell, ESIG/GE
- ✓ Julia Matevosyan, ESIG
- ✓ Charlie Smith, ESIG
- ✓ Mark O'Malley, Imperial College

Developers

- ✓ Orsted (Chair)
- ✓ Enel
- ✓ Invenergy
- ✓ Zenobe
- Nextera
- Iberdrola
- EDF RE
- E.ON
- Acciona

System Operators

- ✓ NG ESO
- ✓ AEMO
- ✓ ERCOT
- ✓ Energinet
- ✓ Eirgrid
- ✓ FinGrid
- 50 Hertz
- MISO
- REE
- TenneT
- Swissgrid

OEMs

- ✓ GE
- ✓ Smartwires
- ✓ Siemens
- ✓ SGRE
- ✓ Hitachi Energy
- SMA
- Mitsubishi
- Toshiba
- Vestas
- Tesla

Software developers

- DigSilent
- Siemens PTI
- GE
- Manitoba Hydro
- EMTP
- Power World
- PowerTech Labs

GFM TECHNOLOGY COUNCIL: NEXT STEPS

2022

- Define GFM services
- Identify first 2 GFM technology demonstrations and develop demo plan (Australia, Great Britain, ERCOT)

2023 - 2025

- Identify additional 3 or more GFM technology demonstrations to support (incl. detailed test plans & funding)
- Document performance requirements ready to be codified and those that require further definition (per OSMOSE)
- Create roadmap of requirements ready to be codified and outline studies/research needed for aspects that can't
- Identify funding of research/studies for GFM aspects that can't be codified
- Development of GFM designs by manufacturers that can meet codified requirements
- Provide guidance to OEMs, software vendors and forward-thinking consultants to enable GFM technology deployment

2025 - 2027

- Full set of GFM equipment features will be available from OEMs around the world
- GFM operating experience acquired by leading system operators will be shared globally

GFMTC OPERATIONS & RHYTHM

Collaboration & interaction between members

- Short statement on IP sensitive issues
- Short statement on commercially sensitive issues

Proposal: Members' agreement on anti-trust issues

Members of the GPST GFMTC agree to:

- Abide by country-level antitrust laws and policies (with global implications)
- Avoid any conduct that unreasonably restrains competition with any member of the GPST
- This includes any agreement between competitors regarding prices, availability of service, OEM-specific product design, developer-specific project design, terms of sale, division of markets, allocation of customers or any other activity that unreasonably restrains competition.

Meeting rhythm

- Periodic virtual meetings
- One or two in-person meetings/year
- Ad-hoc meetings as needed to achieve objectives

GFMTC Demonstration Proposal

Framework of GFM capabilities and performance to be demonstrated & scaled

INPUTS

- Universal Interoperability of GFM Inverters (UNIFI) Specifications
- National Grid ESO GFM Requirements
- NERC Recommendations
- OSMOSE & VDE-FNN GFM Requirements
- HAWAII GFM Project Experience

ADD

- AEMO GFM Experience & Requirements
- Energinet GFM Experience & Requirements

GFM DEMONSTRATIONS VIA FIELD TESTS, MONITORING & MODELING

Performance under normal grid conditions

- Autonomously support the grid
- Provide positive damping
- Coordination of controls (P & Q sharing)
- Robust operation in low system strength grids
- Voltage balancing

Performance outside normal grid conditions

- Ride-through behavior
- Asymmetrical fault response
- Abnormal frequency response
- Response to phase jumps & voltage steps
- Intentional Islanding

Additional Behavior

- Black start and system restoration
- Regulating voltage harmonics
- Secondary voltage & Frequency Signal Response
- IBR short term rated current
- Constraints due to source ("*prime mover*")

Modeling & Documentation

- Model types, structure & parameterization
- Validation of models against field & factory tests
- Demo of GFM performance with validated models where field testing & monitoring is not available

Demonstration plans will be developed for each project
Planned $55M Funding Support ($5M/project + $5M PM support)
Perform demos, develop reports & disseminate knowledge globally

Selection of Initial GFM Demonstration Pilots

Immediate objective: **Pick 2 or 3 existing or imminent GFM plants to demonstrate performance, capabilities, and models based on what we have today or will have soon.**

Ultimate Objective: **Conduct a series of field tests and model validation programs on 5 GFM projects connected in *GW-scale systems*.** Demonstrate individual performance, interoperability and coordination to avoid interactions.

Initial Ideas:

AEMO

- Existing or Imminent BESS projects
  - Dalyrmple, Hornsdale, Wallgrove, Broken Hill, Riverina
- 8 new large GFM BESS projects, 300MW each (ARENA projects)
  - 2025+ Implementation
  - Shaping requirements for these projects
  - ARENA reports & commissioning tests (Potential AEMO knowledge sharing)

National Grid ESO

- Dersalloch GFM Wind Plant
- 5 new GFM BESS projects under development (2024-2026)

ERCOT

- GFM Demonstration in West Texas

What other GFM demo projects can we add?

DEMONSTRATION PHASES

1. Utilize **existing project** commissioning, testing, monitoring and modeling data to demonstrate GFM performance and capabilities.
2. Work with system operators, developers and OEMs on **imminent projects** to implement a GFM testing and monitoring plan.
3. Work with system operators, developers and OEMs to develop an extensive GFM testing, monitoring and modeling program for enhanced demonstration **on new projects**.

Codification of GFM Requirements

1. Document performance requirements ***ready to be codified*** and those that ***require further definition*** (per OSMOSE, GPST and ESIG reports)
   - Leverage existing GFM requirements already developed or being developed in National Grid, AEMO, ENTSOE, UNIFI, etc.
   - Leverage GFM test plans from Hawaii, NERC IRPS, German FNN-VDE requirements, UNIFI, etc.
   - Coordinate with Pillar IV Standards Roadmap
2. Create ***roadmap of requirements*** ready to be codified and outline studies/research needed for requirements that can’t
3. Identify funding of research/studies for GFM aspects that ***can’t yet be codified***
4. Identify and support development of GFM designs by manufacturers that ***can meet codified requirements***

Thank You

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G-PST Support to System Operators

Amy Rose

27 March, 2023

ESIG Spring Conference

Types of Support to System Operators

Grid Integration Solutions

- Roadmaps for control center modernization
- Management and real-time monitoring of power system inertia

Workforce Development

- Partnership with local universities and training institutes
- Specialized continuing education for system operators

Localized Technology Adoption

- Establish or upgrade power electronics testing capabilities
- Expert input on national equipment performance standards

Open Tools and Data

- Open tools to support planning and operation of high RE grids
- Datasets necessary for advanced analysis

Learn more at: https://bit.ly/work-with-gpst

Modes of Support to Country System Operators

- Peer learning with other system operators
- Direct technical assistance and training
- G-PST fellowship program
- Embedded expert assistance
- Learning on research innovations
- Conduct joint applied research

Key Accomplishments

9 country system operator partners

15+ peer exchange webinars and discussions

2 control room upgrade plans developed

1 control room tool deployed

4 staff fellowships

45+ system operator & research institution staff contribute to peer learning

Control Room Upgrades

- G-PST experts from NREL, EPRI, ERCOT, and CAISO provide recommendations for developing a new Control Center for the Java-Bali and Sulawesi grids for **Indonesia's PLN**
- **Peru's COES** teamed up experts from NREL and EPRI to develop a roadmap for updating its control room
- Lessons learned from these activities and groundbreaking research from founding system operators on advanced **control room design** shared publicly:
  - Control Center of the Future Road Map for Peru's System Operator
  - Designing a Future-Oriented Control Center System for Successful Energy Transition
  - Industry and Researcher Perspectives on Control Center Upgrade Procurement
  - Designing Control Rooms to Support High Penetrations of Variable Renewable Energy
  - Use of AI and Big Data in the Control Room
  - Organizational Structure of the Control Center of the Future

Open Tools

- NREL and EPRI are partnering with **Vietnam's NLDC** and **South Africa's Eskom** to develop an open tool for system inertia monitoring.
- G-PST experts are worked with engineers at **India's Grid-India** to deploy open-source tools to detect sources of network oscillations.
- Publicly available resources on Open Tools and Data provide a scalable solutions to meet emerging needs:
  - ➢ Building an Open-Source Strategy at Power Grid Operators
  - ➢ Open-Source Power Systems Analysis Packages: Workflow and Benchmarking on Common Load Flow Problem
  - ➢ Inverter-Based Resource (IBR) Research Team Stability Tools Inventory: Status and Needs
  - ➢ Open-Source Tools for System Operators – Focus on Power Flow Tools

Peer Learning on Priority Topics

- **Indonesia's PLN** system operator staff have participating in 10 knowledge sharing sessions with Founding System Operators and technical institutions on priority topics including SCADA/EMS architecture, grid codes, and control room procurement.
- Founding System Operators and G-PST experts are responding to requests from **Colombia's XM** and **Vietnam's NLDC** for peer learning on technical topics of most interest including distributed PV, system flexibility, resiliency metrics, and reactive power and voltage optimization
- NREL, MISO, and POSOCO supported a webinar on cyber security related challenges for electric utilities for **Indian state load despatch centres**.

Thank you

Amy.Rose@nrel.gov

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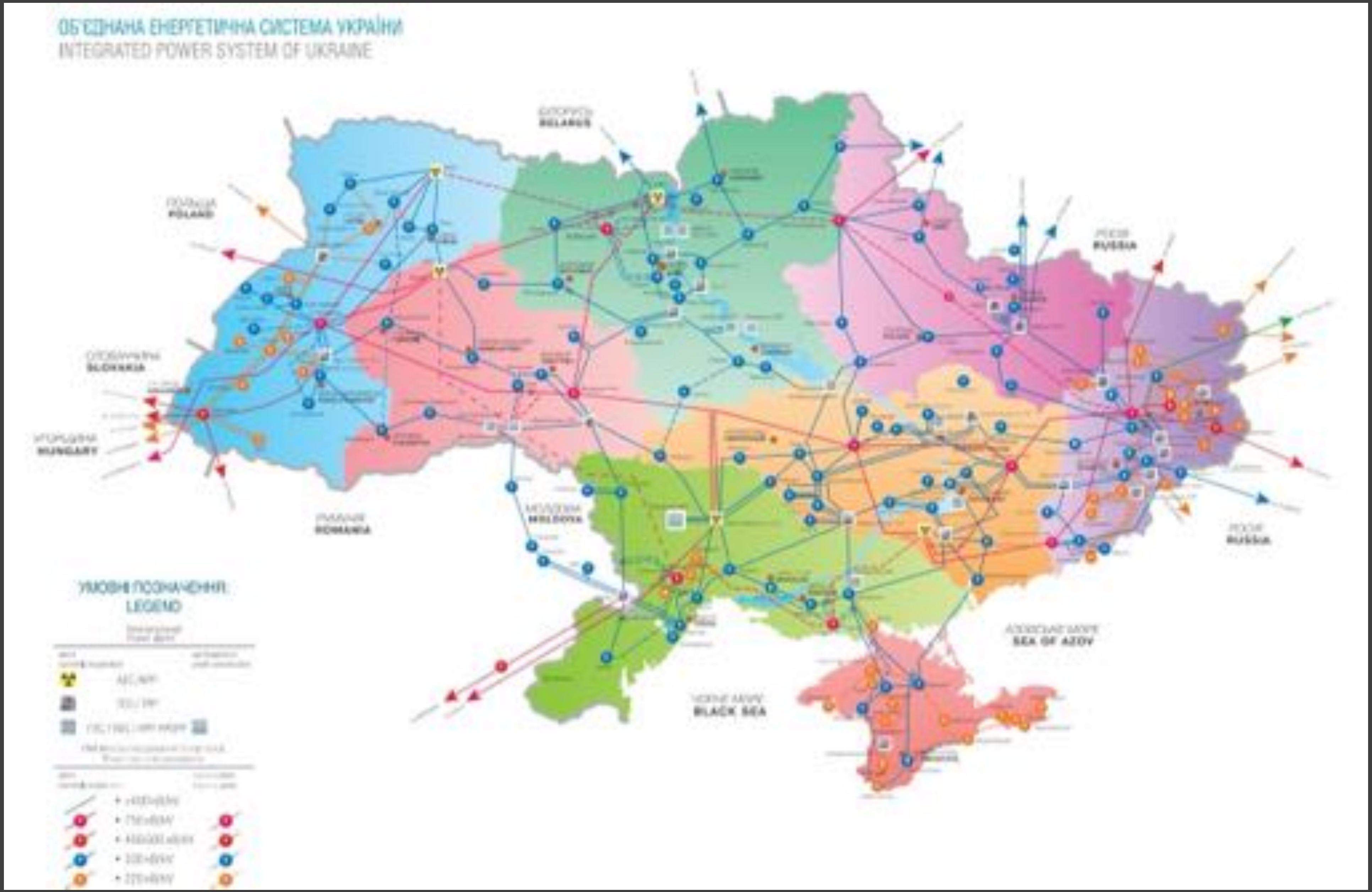
УКРЕНЕРГО
Національна енергетична компанія

Recent Experiences Power System Repair Restoration Activities

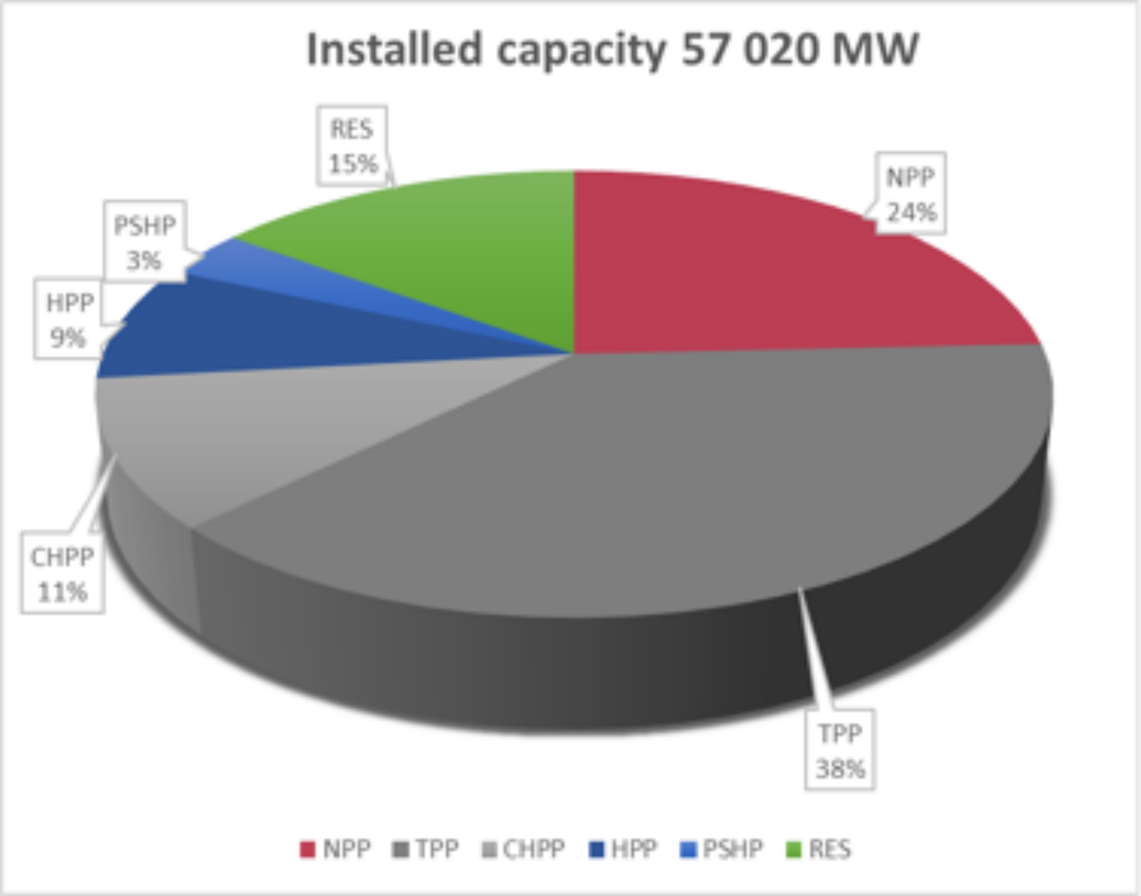
Department of Balance Reliability
Department of Operational Dispatch and Reliability of IPS

Integrated Power System (IPS) of Ukraine



Generation capacity mix of Ukraine

- 4 NPP with 15 reactors – 13.8 GW
- 15 TPP – 28.4 GW
- 8 HPP – 5 GW
- 2 PSHP – 1.7 GW
- Solar PV – 6.6 GW
- Wind – 1.5 GW



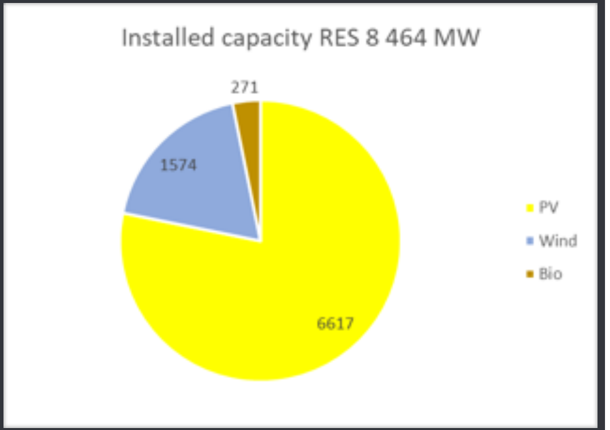
Past decade was in extremely unfavorable conditions:

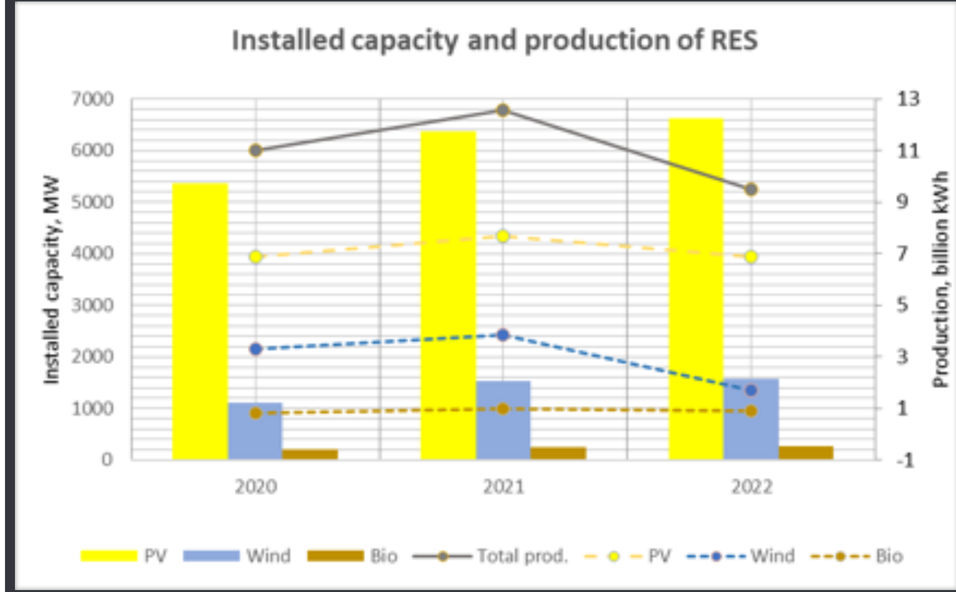
- ***exogenous factors*** connected with the russian occupation of part of the Ukrainian territory in 2014-2022 that formed a scarcity of flexible capacity
- ***endogenous factors*** connected with unbalanced development of generation capacity with the rapid penetration of RES, which was not accompanied by the parallel introduction of flexible capacities in the necessary volumes

Additional challenges:

- problems of ensuring the **necessary volumes of reserves** (in accordance with the Grid Code), which is not possible with the use of existing equipment
- the problem of **covering the fuel component** on the electric energy market for several TPPs and CHPPs
- lack of financial resources for the restoration of energy facilities in the war and post-war periods and for their development in the post-war period

RES

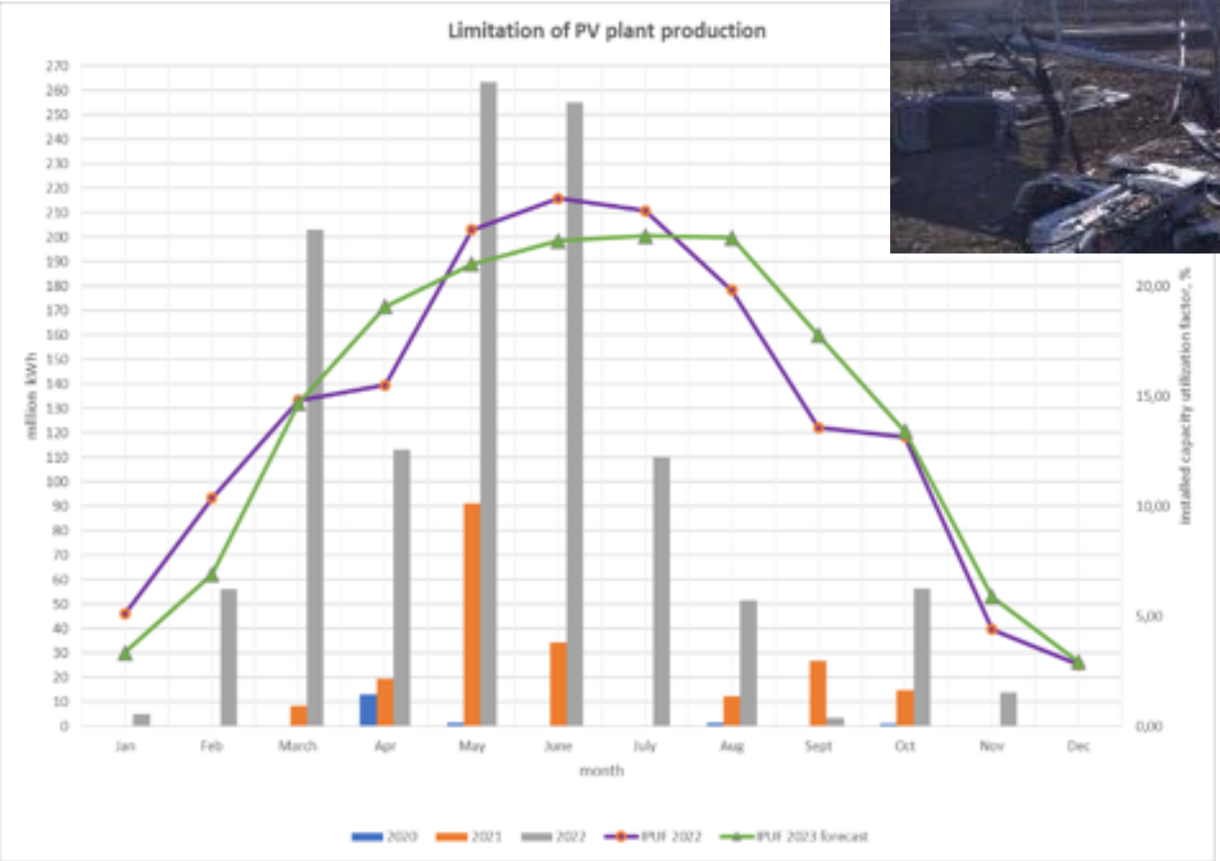




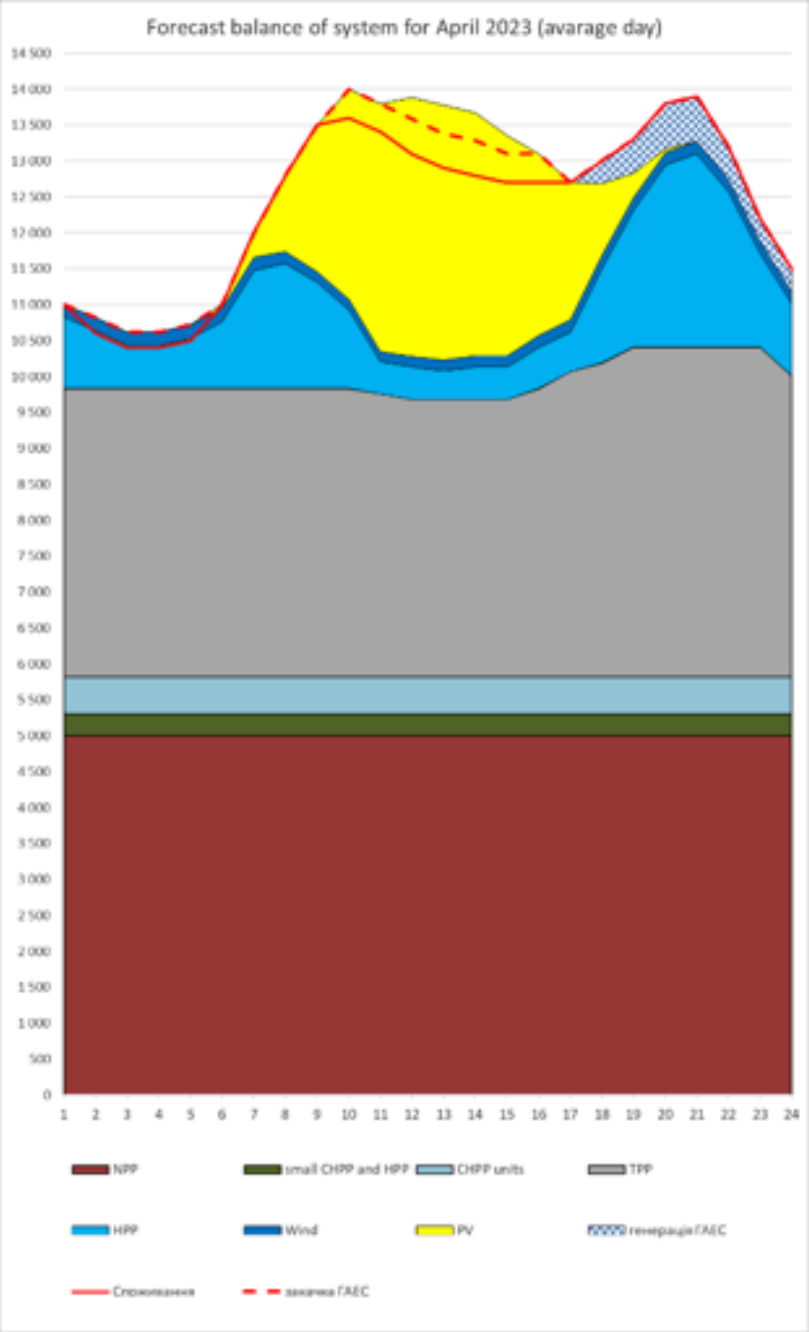
<u>To ensure the balance reliability and development of RES, the following changes to the Law are the most important:</u>

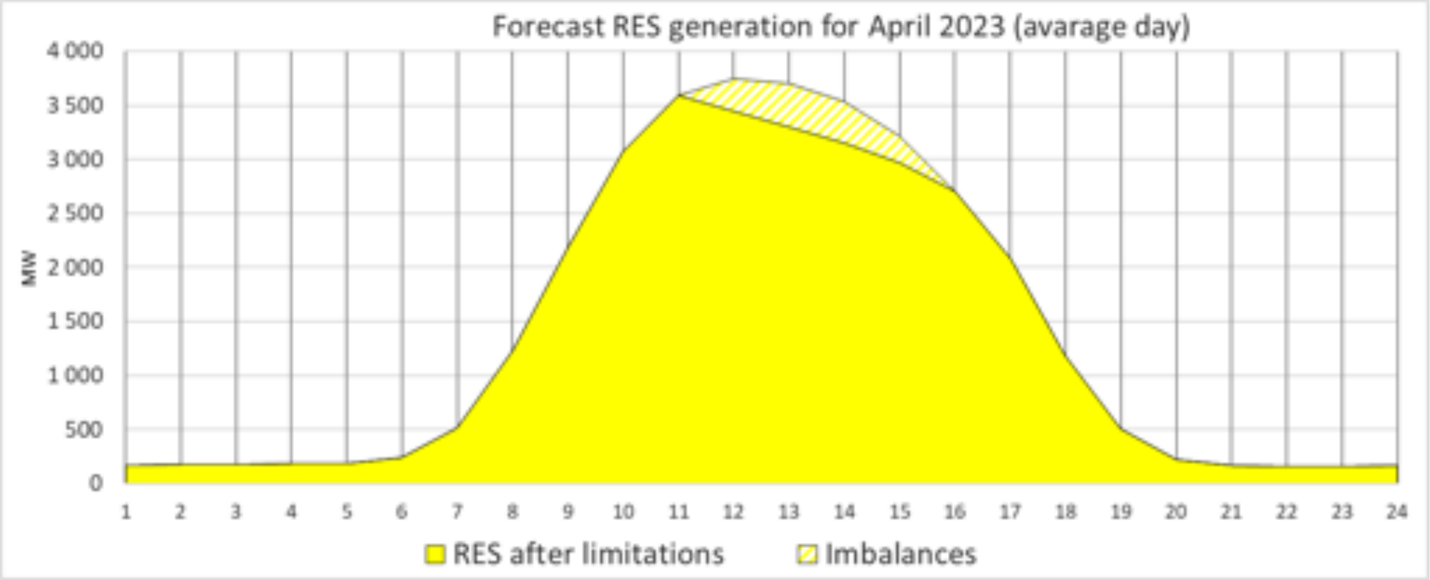
✓ ***RES load reduction services with support***

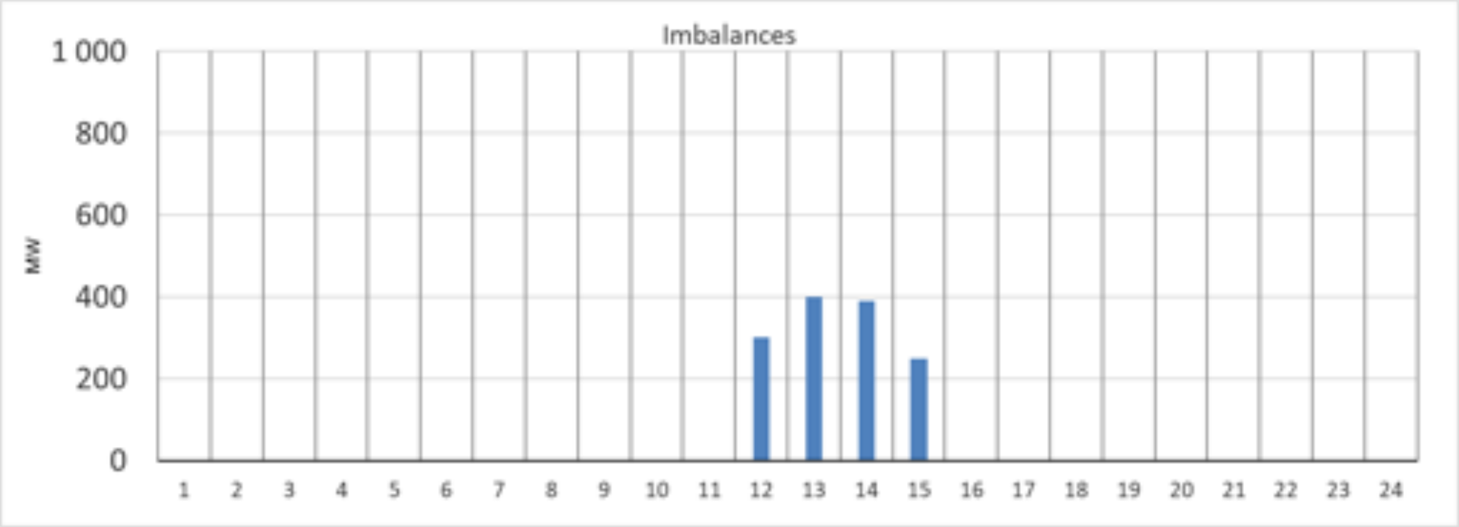
from 01.01.2021, producers who have been set a "green" tariff, or who, as a result of the auction, have acquired the right to support (RES), **are obliged to submit offers** to TSO regarding the **provision of load reduction services** in volumes that correspond to the daily electricity supply schedule, and in the opposite case - are obliged to provide services on the balancing market in accordance with the Market Rules. TSO provides orders to reduce the RES load in exceptional cases when all options for balancing have been exhausted. Payment for the energy not released.



RES limitations connected with balancing







Synchronization with ENTSO-E

1 July 2002 – from July 1, 2002, "Burshtyn island" worked synchronously with CE SA

2013 – Association Agreement with the EU (Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other hand)

2017 – in 2017, after a long process of ratification, the Association Agreement between Ukraine and the EU entered into force in full

2017 – Agreement on the conditions for the future connection of the power systems of Ukraine with the power system of Continental Europe

2019 – transition to a new model of the EU market

23 Feb. 2022 – switched the "BuTPP island" to synchronous operation with the IPS of Ukraine

15 Mar. 2022 – **24.02-15.03.2022** isolated mode

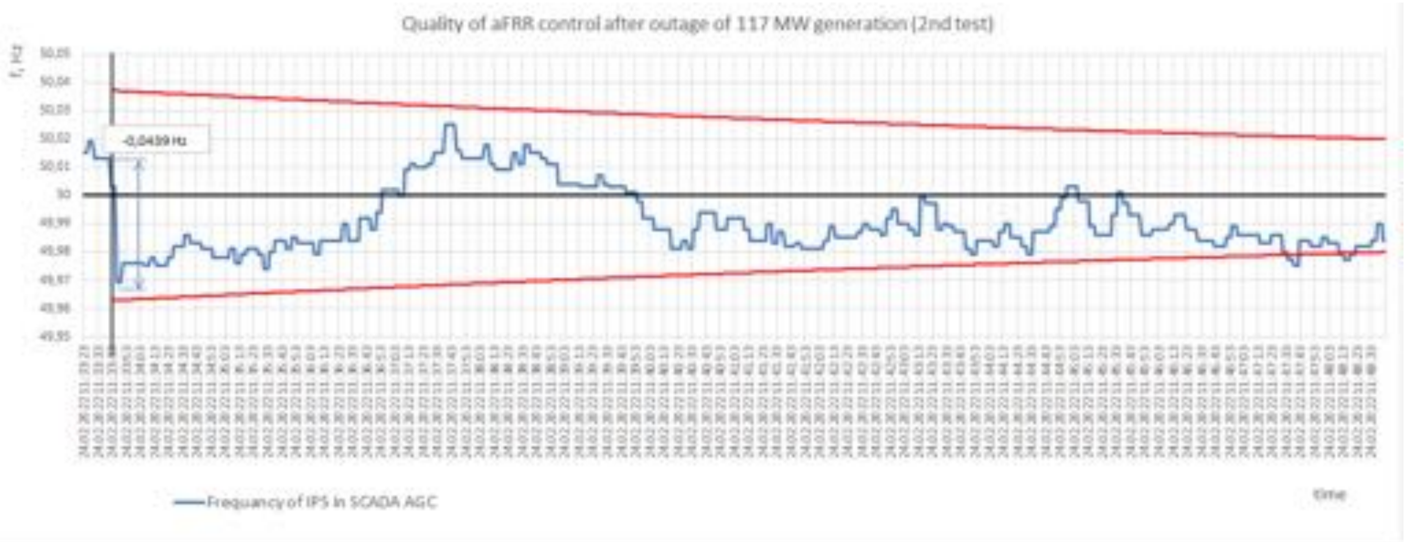
16 Mar. 2022 – from **March 16, 2023** – emergency synchronization with CE SA

Goals and benefits

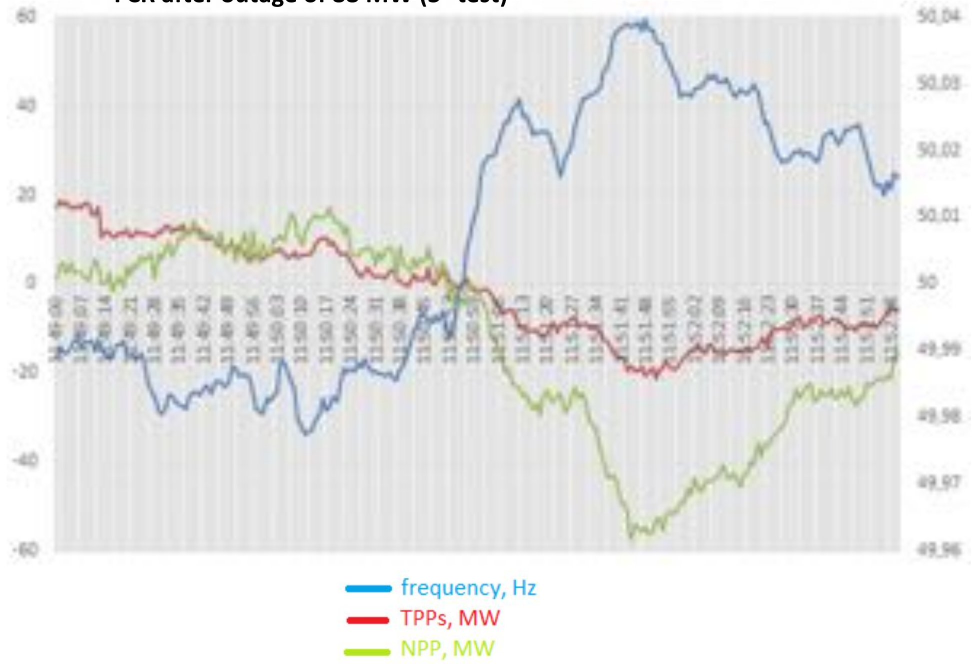
- Energy independence and security
- Decarbonization of the Ukrainian energy industry
- Realization of export and import potential
- Transparency and demonopolization
- Investments
- Increasing the reliability and stability of the ENTSO-E energy union by increasing the inertia carried by our equipment
- Additional FCR for ENTSO-E

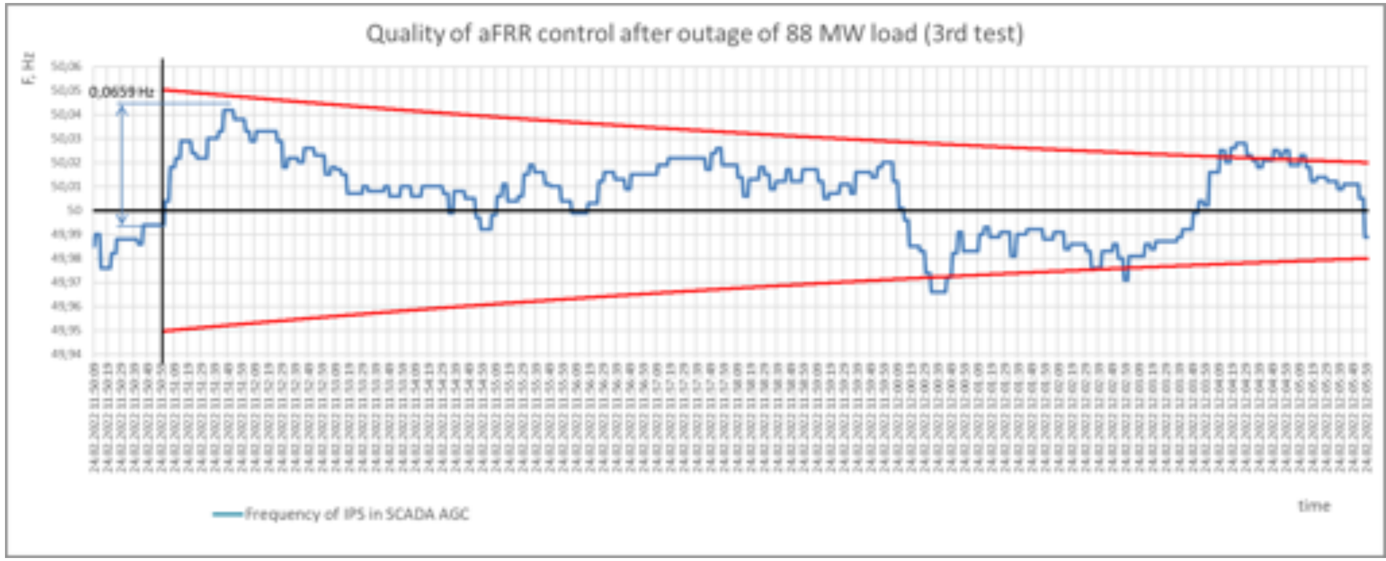
Isolated mode / Trials

FCR after outage of 117 MW (2nd test)

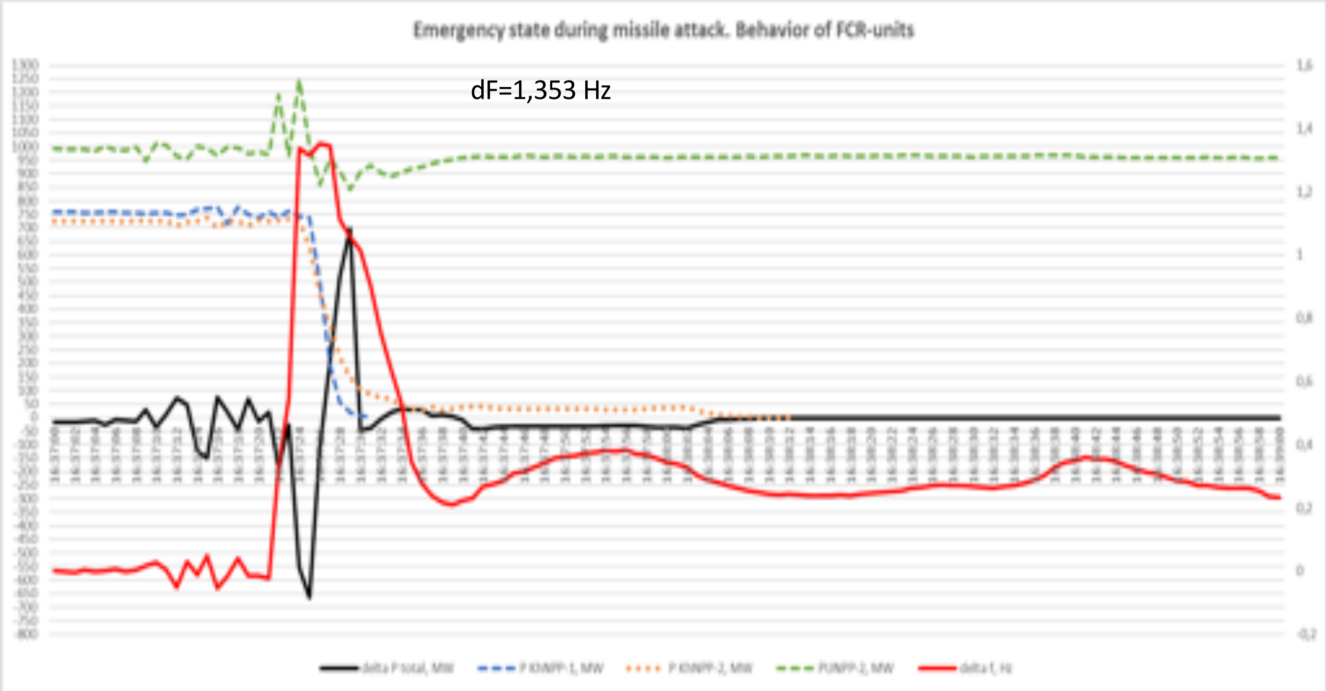


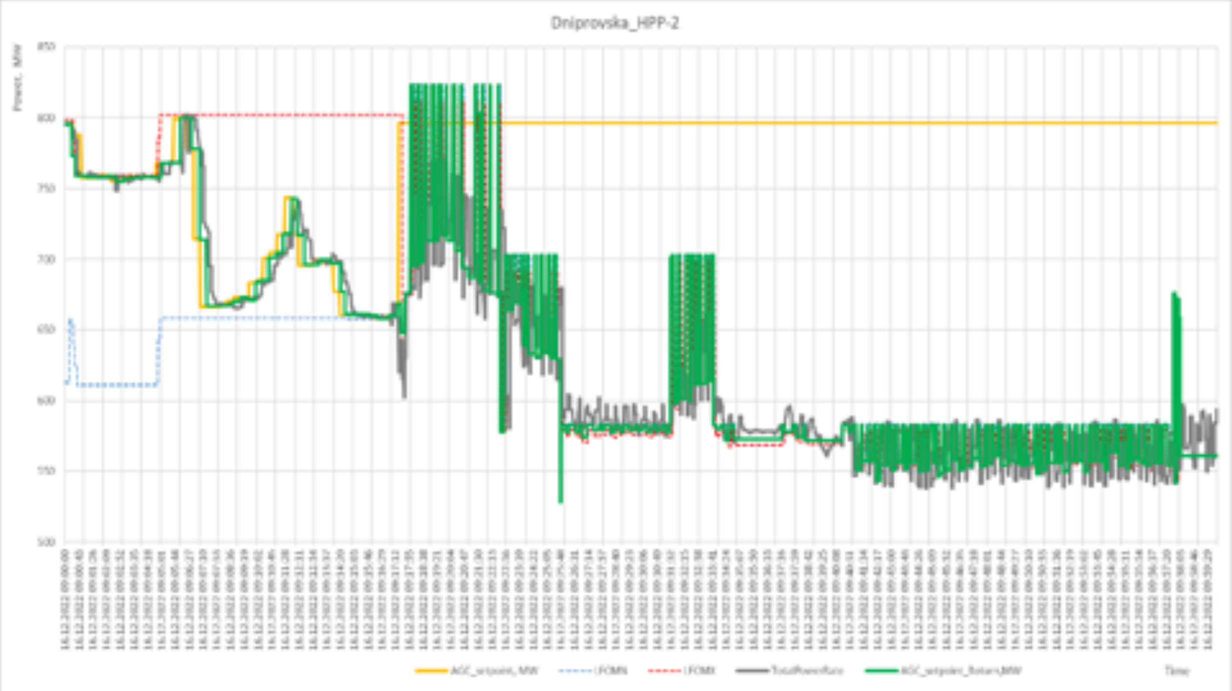
FCR after outage of 88 MW (3d test)



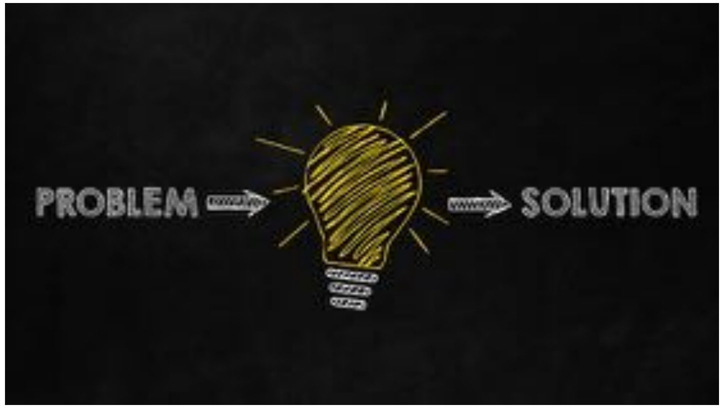


Routine FCR-units and Emergency events





Problems of the IPS operation (including the war time) and prospects



- provision of reserves, changes in volumes due to destruction, in comparison with the beginning of 2022
- scarcity of maneuvering and peak generation
- network problems, consequences of missile attack and shelling
- compliance with environmental requirements
- application of emergency and planned schedules of disconnection of consumers (load shedding) from September 2022 till January 2023, scarcity reached 4500 MW
- RES limitation
- occupation ZNPP and group of RES

- ❑ **implementation of RES integration support technologies**
- ❑ **mechanisms of payment for capacity**
- ❑ **increasing the capacity of the Tashlytska PSHP**
- ❑ **additional units on Dniestrovska PSHP**
- ❑ **reconstruction of existing capacities**
- ❑ **small modular nuclear reactors**
- ❑ **ESS for frequency control (primary and secondary)**
- ❑ **technologies for the elimination of surpluses in the energy system**

Assistance of the countries of the world in overcoming the consequences of destruction and damage of electric power equipment (emergency assistance, import, supply of equipment (high-voltage transformers, gas turbine installations…), advisory assistance....

GOALS

Create optimal and reliable stable modes of operation of the trunk network

Ensure uninterrupted operation of the power system

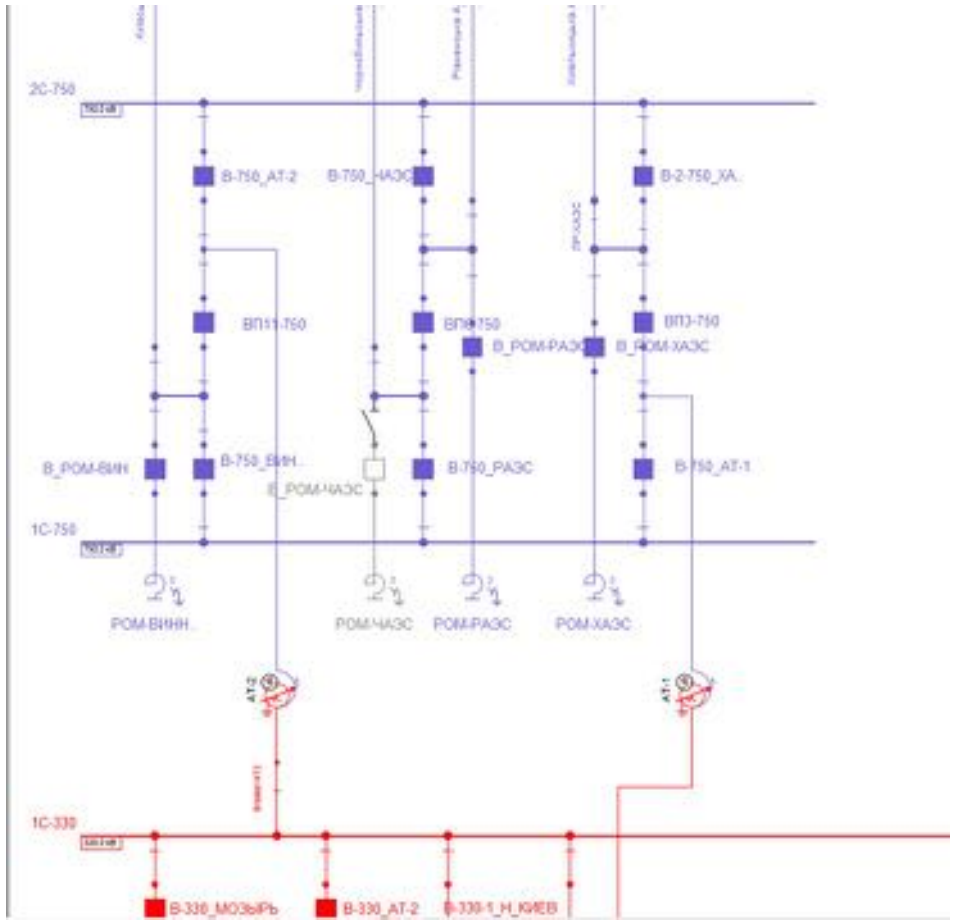
Ensure the minimum technological losses from transmission

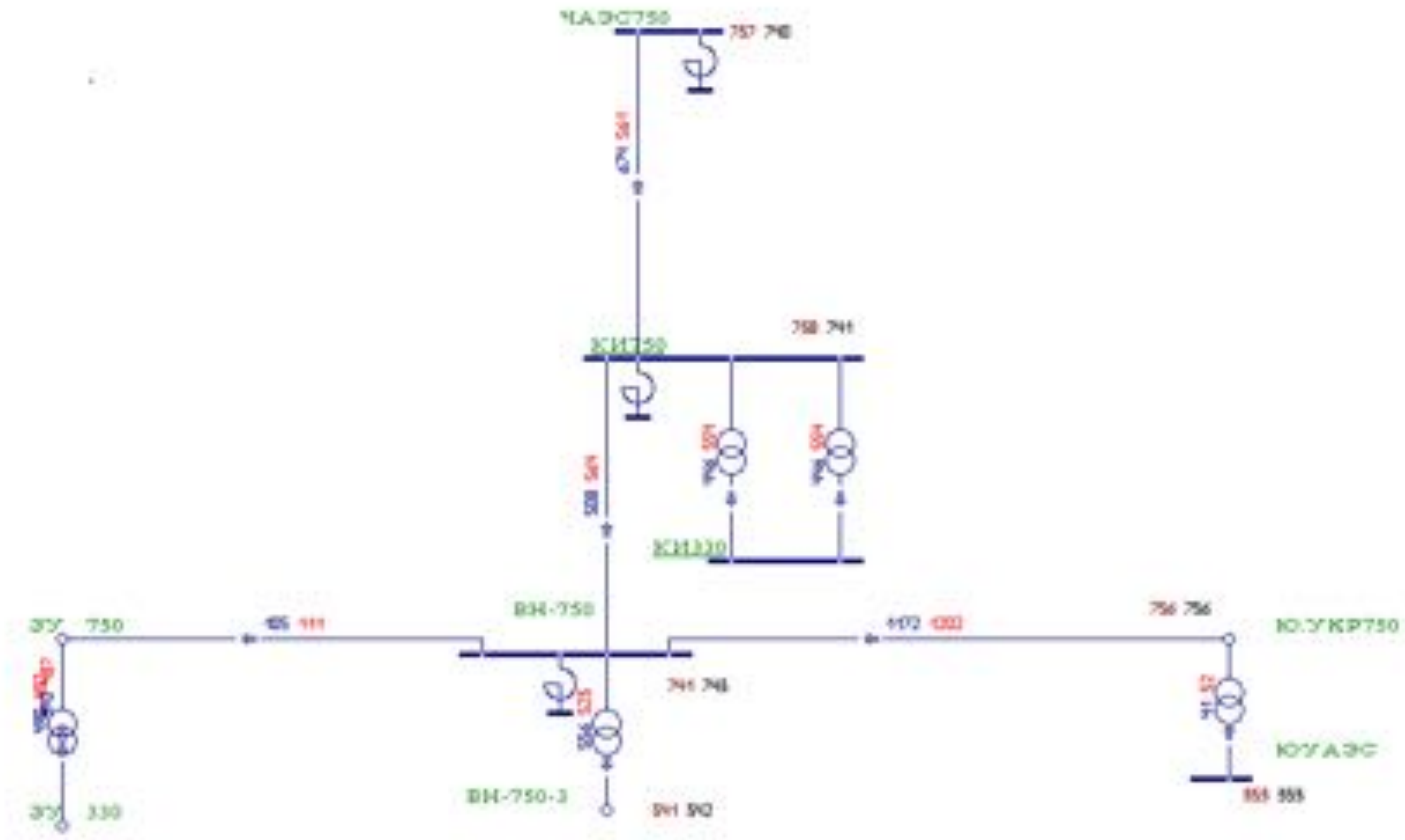
Create optimal and reliable stable modes of operation of the trunk network

- switch on/off shunt reactors of 750 kV
- by changing the positions of the switching devices of longitudinal voltage regulation (on-load tap-changer) at AT 750/330 k
- monitoring the transmission system parameters in real-time by SCADA EMS:
  - ✓ active and reactive power flows
  - ✓ busbar voltages
  - ✓ active and reactive power reserves
  - ✓ generation and load

Ensure the minimum technological losses from transmission

- shutdown one of the low-load autotransformers in the substation operating in parallel
- by changing the positions of the switching devices on the transverse voltage regulation transformers included in the neutral of the AT 750/330 kV





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КИ750
КИ330
ВН-750
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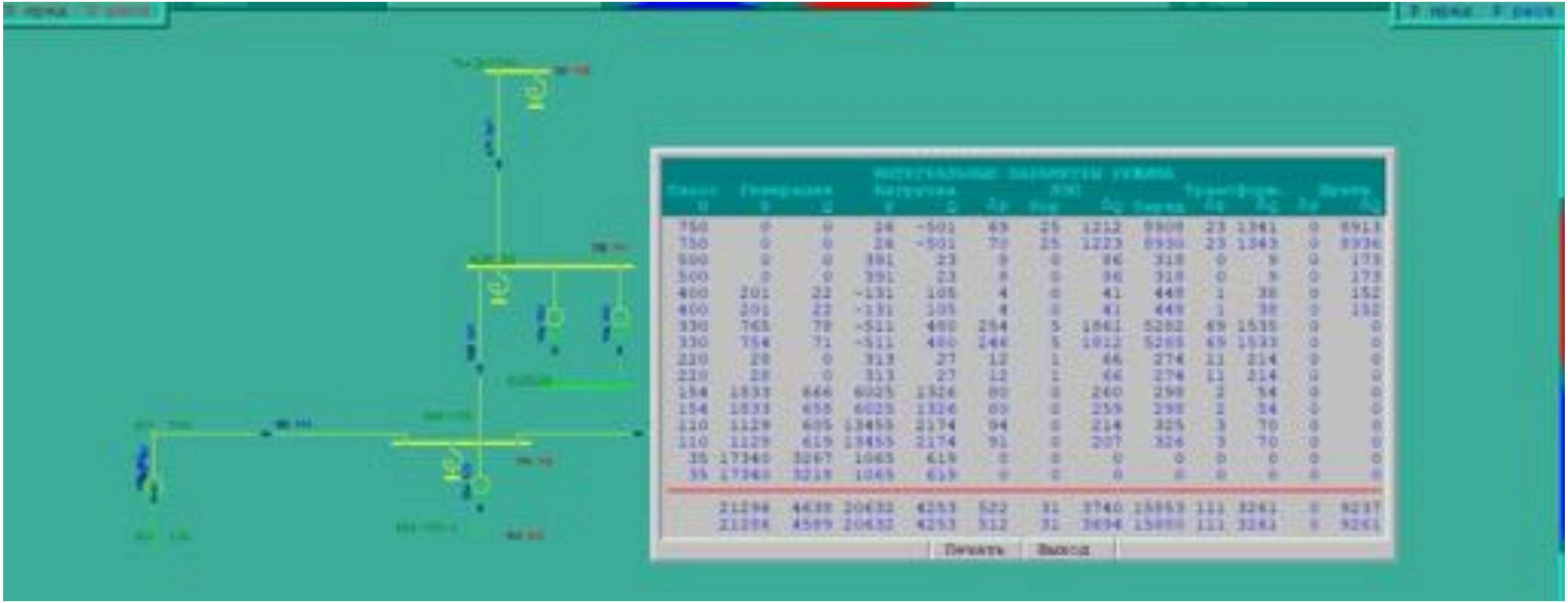
ЗУ 330
ВН-750-3
ЮУКР750
ЮУАЭС



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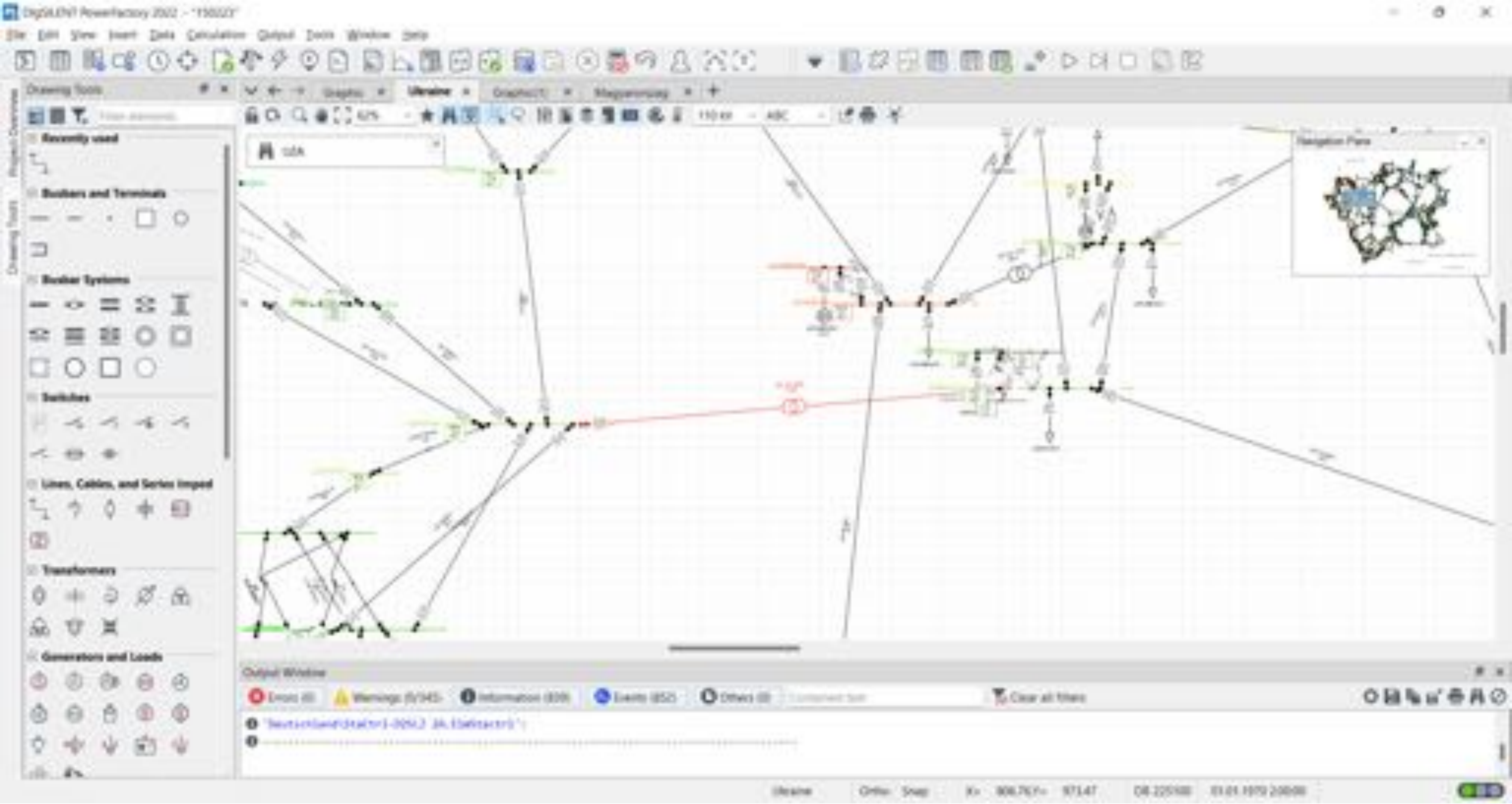
35	17340	3267	1065	619	0	0	0	0	0	0	0	0
35	17340	3219	1065	619	0	0	0	0	0	0	0	0
	21298	4638	20632	4253	522	31	3740	15853	111	3261	0	9237
	21258	4599	20632	4253	512	31	3694	15880	111	3261	0	9261


DIgSILENT PowerFactory 2022
File Edit View Insert Data Calculation Output Tools Window Help
Drawing Tools
Recently used
Busbars and Terminals
Busbar Systems
Switches
Lines, Cables, and Series Imped
Transformers
Generators and Loads
Ukraine
Navigation Pane
Output Window
Clear all filters

УКРЕНЕРГО
Національна енергетична компанія

THANK YOU FOR ATTENTION

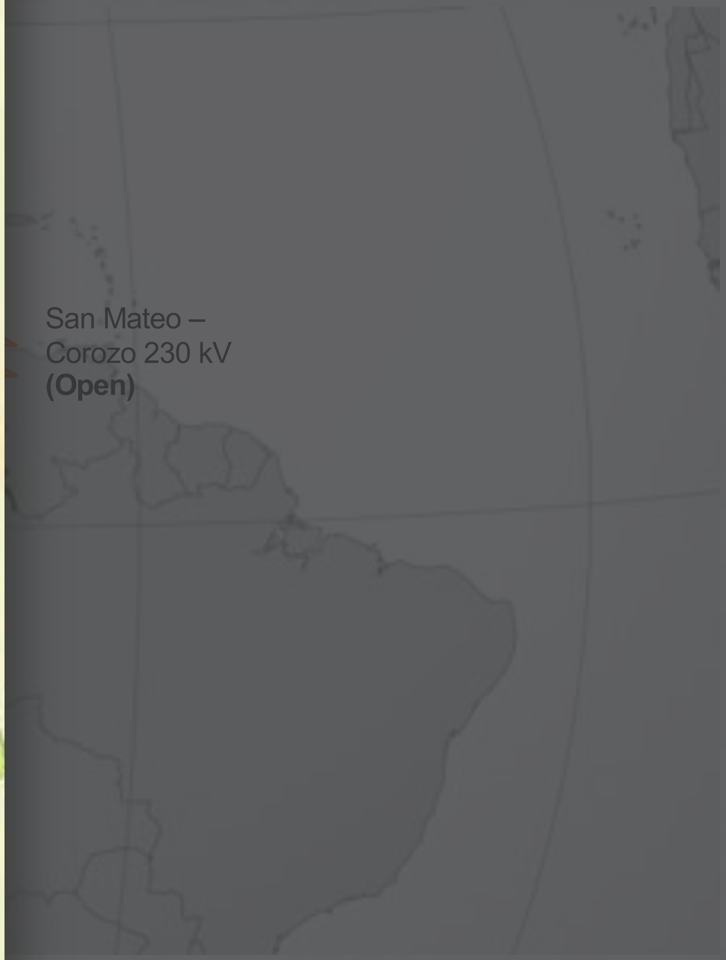
XM
Sumamos energía,
sumamos pasión

Variable Renewable Energy Challenges and Considerations on the Colombia Power System

Jorge Mola and Julian Castaño

Basic Facts &

- **Peak load:** 10.8 GW
- **Annual energy con**
- **Population:** 51,609
- **Area:** 1,141,748 km
- **Number of ISOs:** 1
- **Number of Transm**
- **Number of Generat**
- **Number of Distribu**
- **Number of Retailer**



Sumamos energía,
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Basic Facts & Colombian Power System

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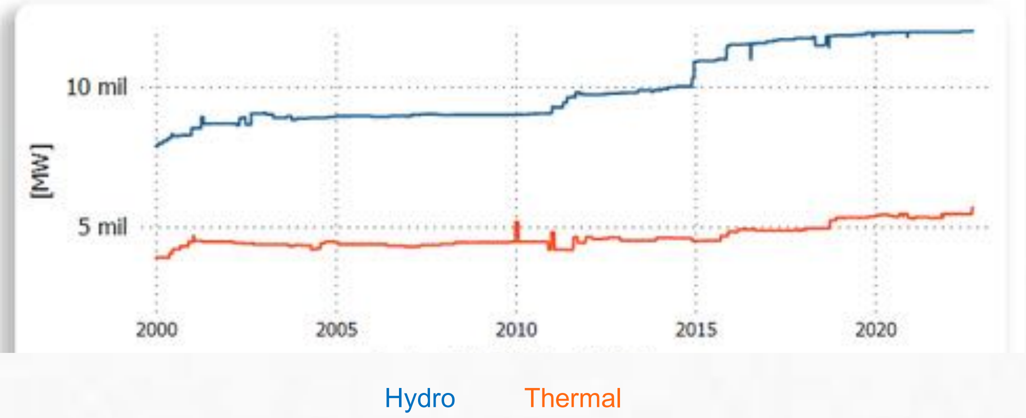
Capacity & Energy

Generation Capacity Evolution

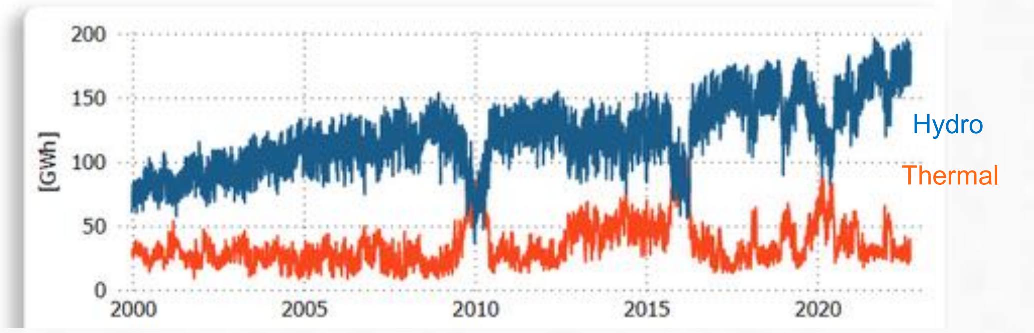


2022 →

Installed capacity

Hydro:	12.6 GW	- 67%
Thermal:	5.7 GW	- 30%
Solar:	0.3 GW	
Other:	0.1 GW	
Total:	**18.7 GW**	

Evolution of Hydro and Thermal Generation

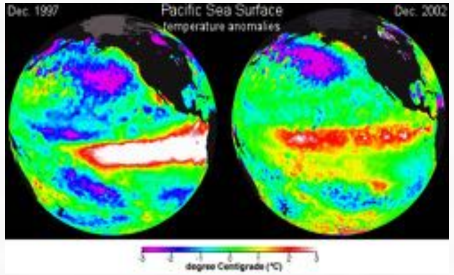


Colombia is high dependent of hydro generation, which makes Colombia´s power system vulnerable to dry events

Hydro and thermal Generation

Usually:		Hydro 80% - Thermal 20%
Dry Season:		Hydro 49% - Thermal 51%
Today:	Solar 3% -	Hydro 90% - Thermal 6%

→ **Extreme Dry events – *El Niño Southern Oscillation* (ENSO)**



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Future Generation Capacity

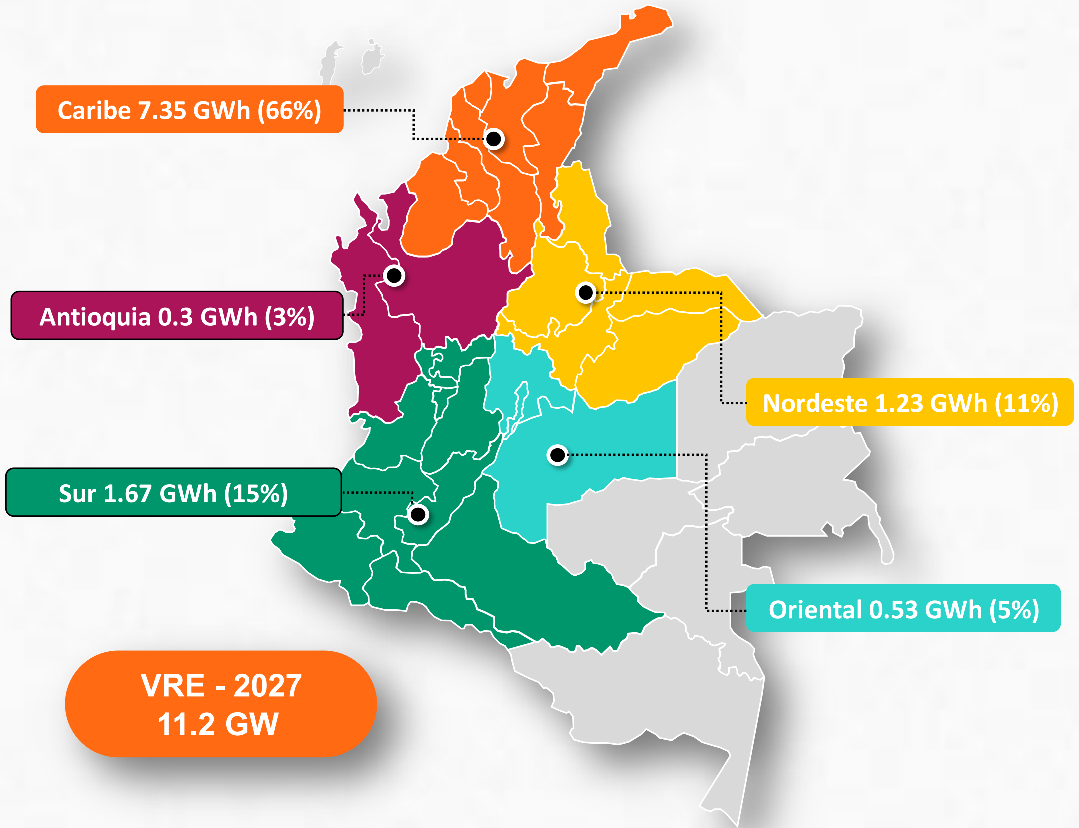
31.2 GW - 2027

Solar 8.5 GW (28%)

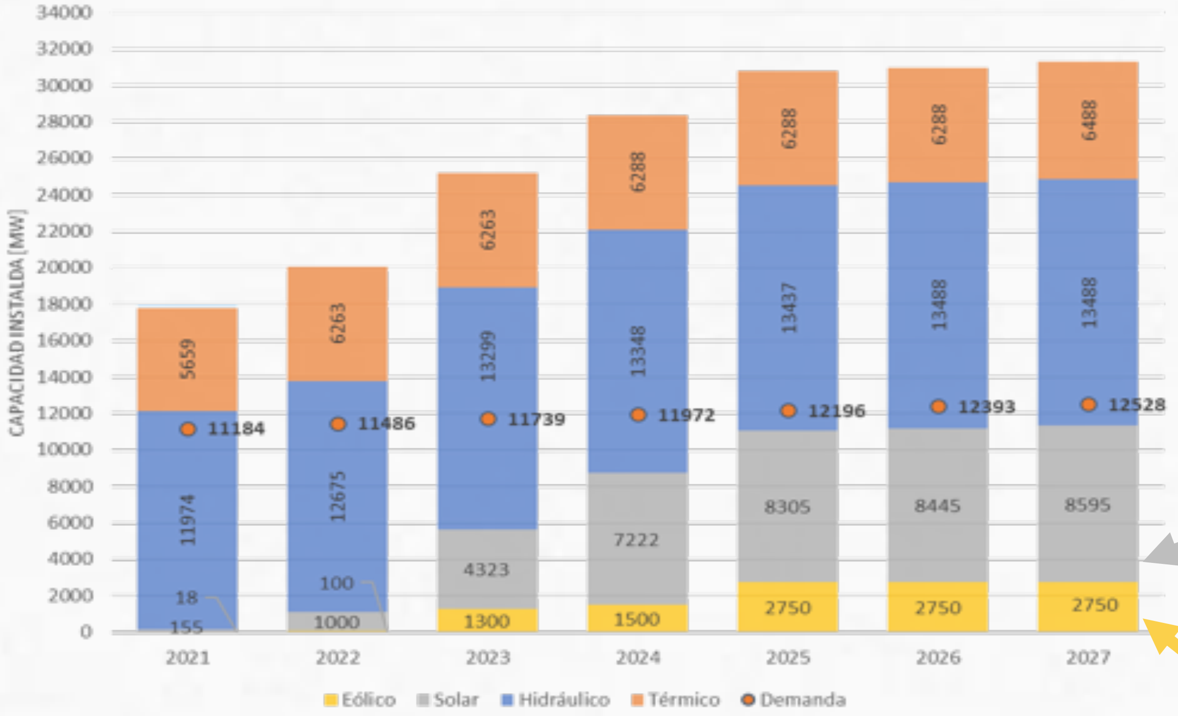
Wind 2.7 GW (9%)

Hydro 13.5 GW (43%)

Thermal 6.5 GW (21%)



VRE - 2027
11.2 GW



Current challenges

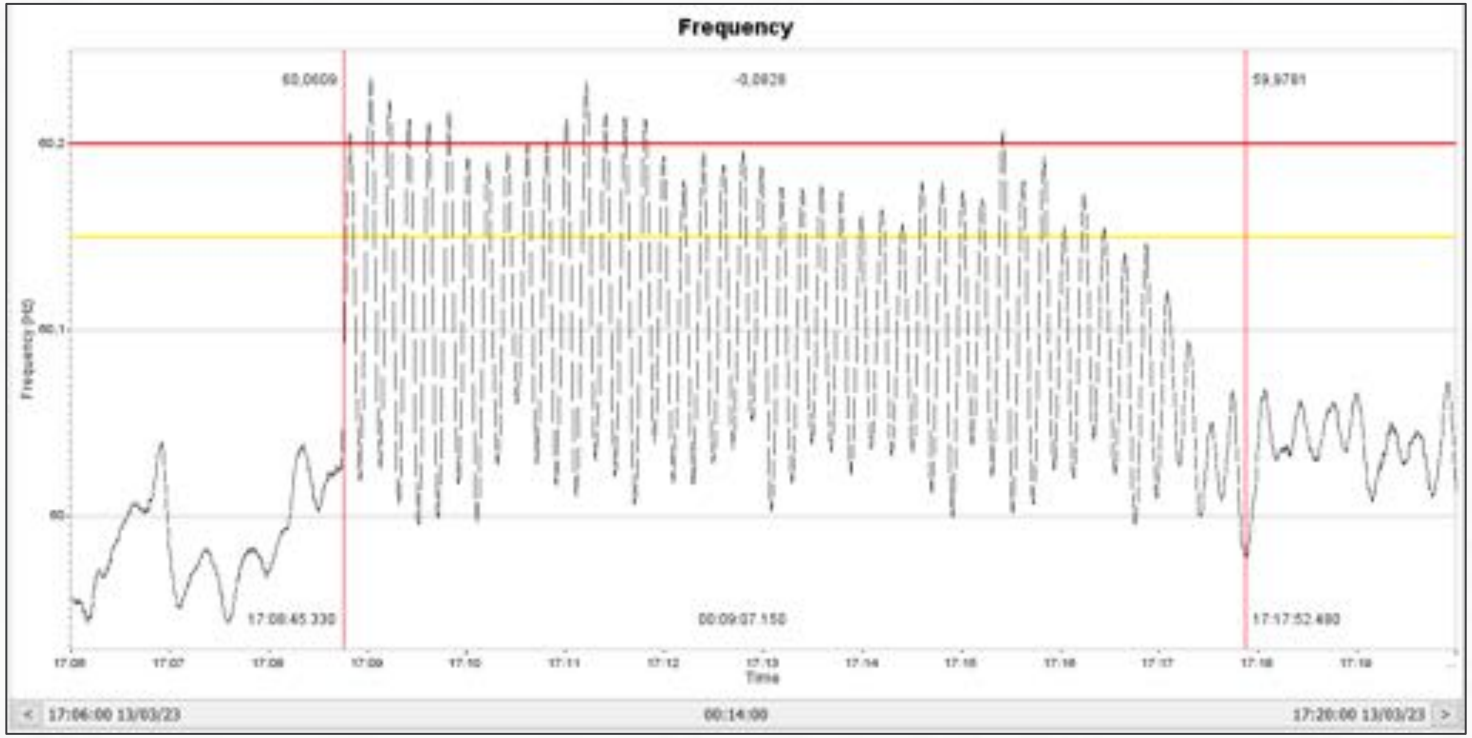
Frequency oscillations:

Mode Frequency: 0.08 Hz

Duration: 9 minutes 7 seconds

Max Mode Amplitude: 97 mHz

Min Mode Damping: 1.5 %



Current challenges

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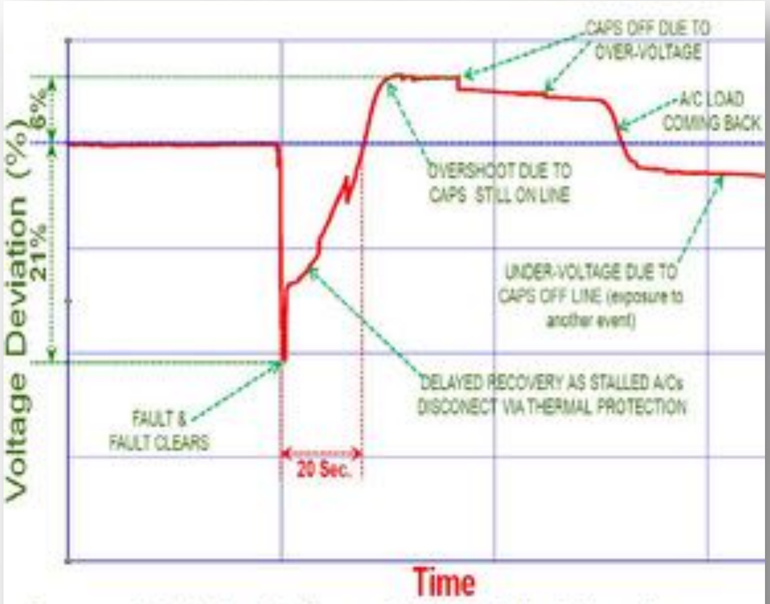
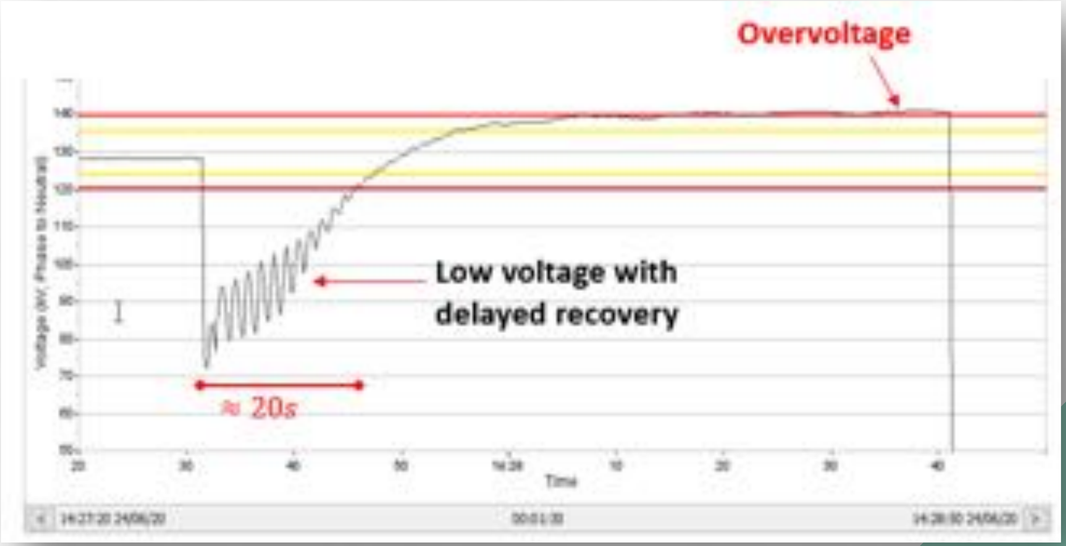
Fault-Induced Delayed Voltage Recovery

1) Stalling of induction motors;
2) Initial voltage recovery after the clearing of a fault to less than 90 percent of pre-contingency voltage; and
3) Slow voltage recovery expected post-contingency



Source: A Technical Reference Paper: Fault-Induced Delayed Voltage Recovery. Version 1.2. Prepared by: NERC Transmission Issues Subcommittee and System Protection and Control Subcommittee. June 2009



Actual case in the Colombian system

Current challenges

Sumamos energía,
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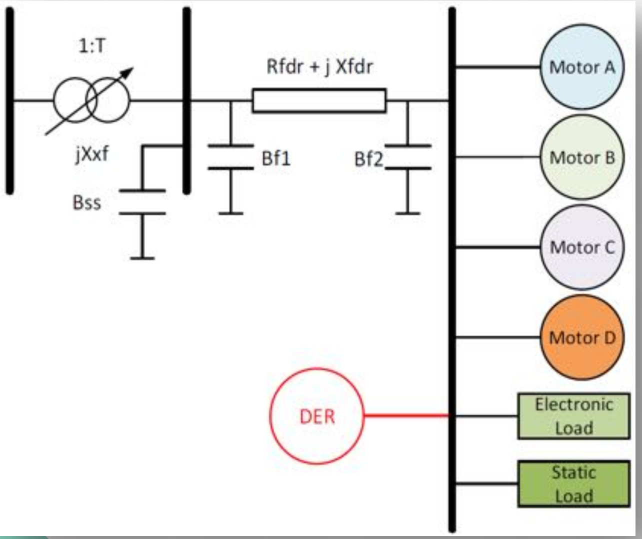
Fault-Induced Delayed Voltage Recovery

At XM we are implementing the WECC composite load model for dynamic simulations in order to replicate the phenomenon in our electrical simulation software.



Element	Application
Motor A	A/C compressors (industrial and commercial) and refrigeration systems.
Motor B	Commercial fans and air treatment systems.
Motor C	Commercial water circulation pumps in central refrigeration systems
Motor D	It represents single-phase motors for residential air conditioning compressors

How to avoid the the FIDVR?

- ❑ Synchronous condenser.
- ❑ GFM STATCOM
- ❑ GFM Batteries
- ❑ ¿ ?

Challenges with the dynamic model:

1) Difficulty to obtain the parameters for each element.
2) Increased running time in each simulation.

Taken from: https://www.wecc.org/Reliability/WECC%20MVWG%20Load%20Model%20Report%20ver%201%200.pdf

Current challenges

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Grid strength metrics

XM computes system strength metrics to inform about possible controller instabilities:

$$WSCR = \frac{\sum_j (S_j * P_j)}{\left(\sum_j P_j\right)^2}$$

$$CSCR_i = \frac{S_i}{\sum_j P_j}$$

$$SCRIF_i = \frac{SCMVA_i}{P_i + \sum_j (IF_{ji} \times P_j)}$$

$$IF_{ji} = \frac{\Delta V_i}{\Delta V_j} \cong \frac{\Delta Z_i}{\Delta Z_j}$$ [1]

Table C.1—Comparison of system strength metrics

Metric		Simple calculation using short-circuit program	Accounts for nearby inverter-based equipment	Provides common metric across a larger group of IBR	Accounts for weak electrical coupling between plants within larger groups	Considers non-active power inverter capacity[a]	Able to consider individual sub-plants within larger groups
SCR	Short-circuit ratio	Yes	No	No	No	No	No
CSCR	Composite SCR	Partial	Yes	Yes	No	No	No
WSCR	Weighted SCR	Partial	Yes	Yes	Partial	No	No
SCRIF	Multi-infeed SCR	No	Yes	N/A	Yes	Yes	Yes

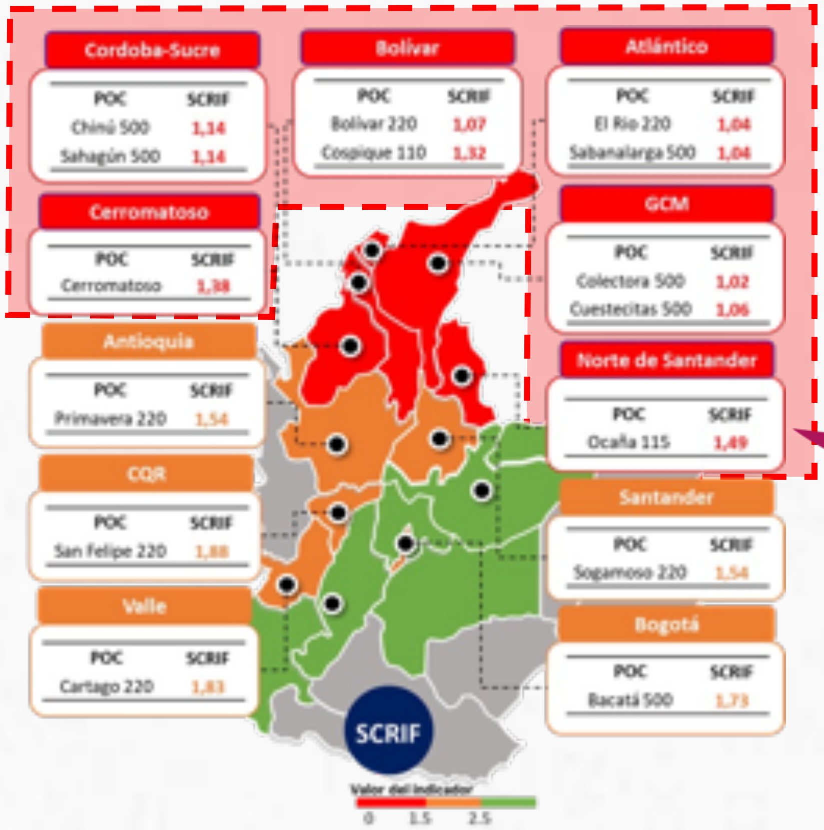
Taken from IEEE 2800 - 2022

[1] Xia C, Hua X, Wang Z, Huang Z. Analytical Calculation for Multi-Infeed Interaction Factors Considering Control Modes of High Voltage Direct Current Links. Energies. 2018; 11(6):1506. https://doi.org/10.3390/en11061506

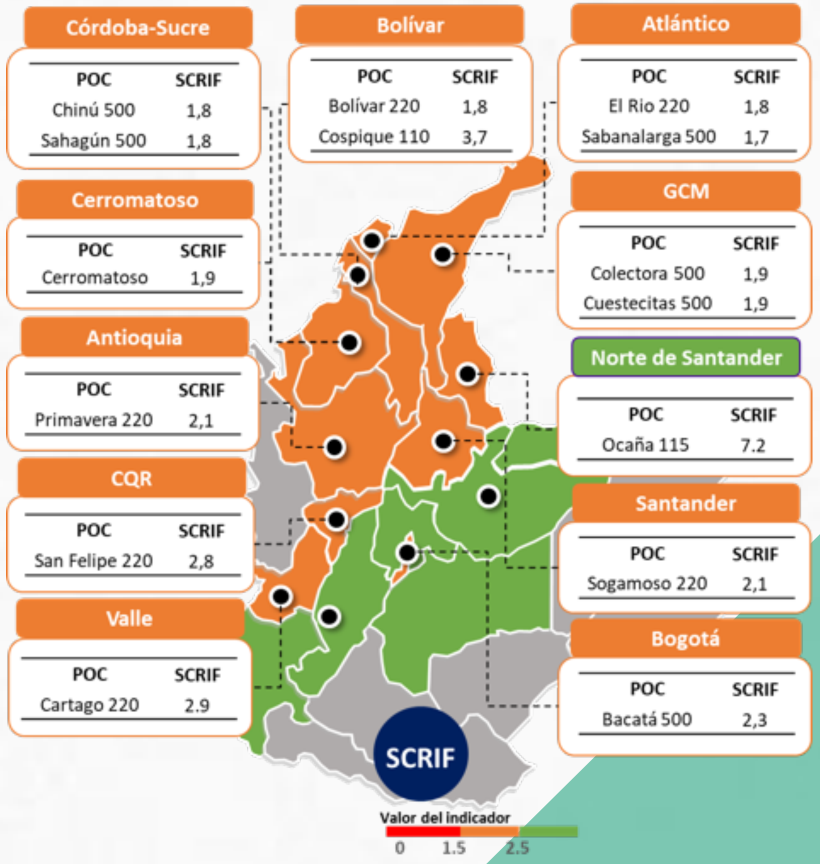
Current challenges

XM Sumamos energía, sumamos pasión

Grid strength metrics



Considering synchrhonous condensers in the northen region



How do we measure the readiness of the system for this challenge?

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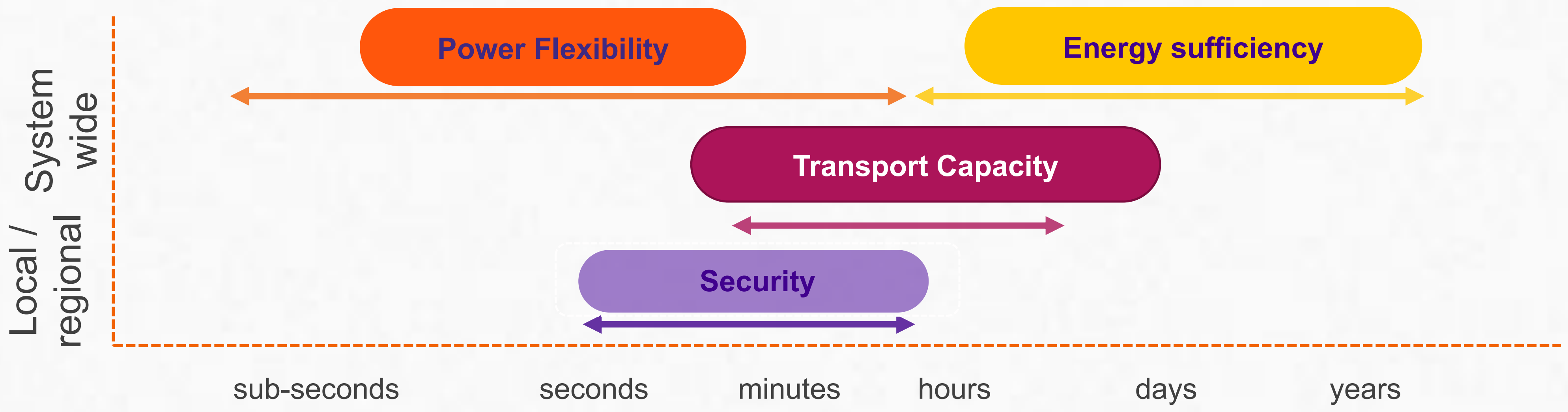
Energy sufficiency: focuses on the supply of electricity in the medium and long term.

Power Flexibility: Studies the generation-demand balance hour by hour.

Transport capacity: Ability to transport energy while maintaining safety.

Security: Requirements for reactive power and stability studies.



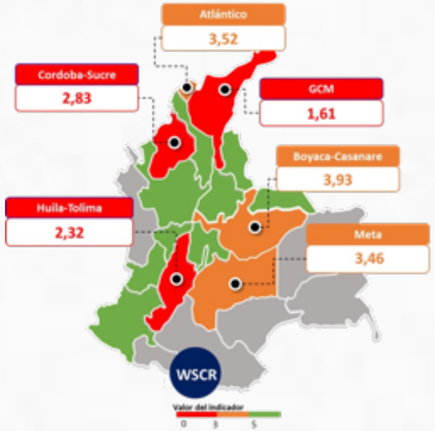
Taken from: Emil Hillberg et.al. Flexibility needs in the future power system. ISGAN. Marzo 2019.

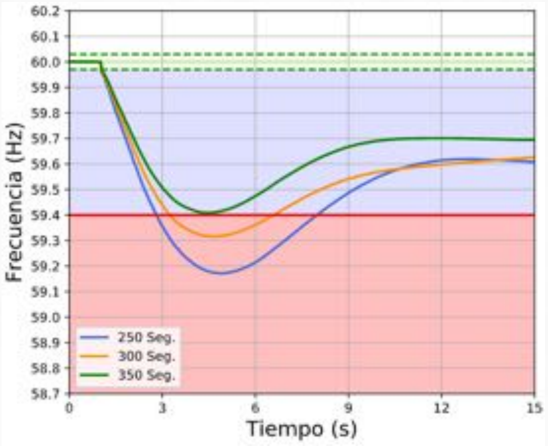
Security

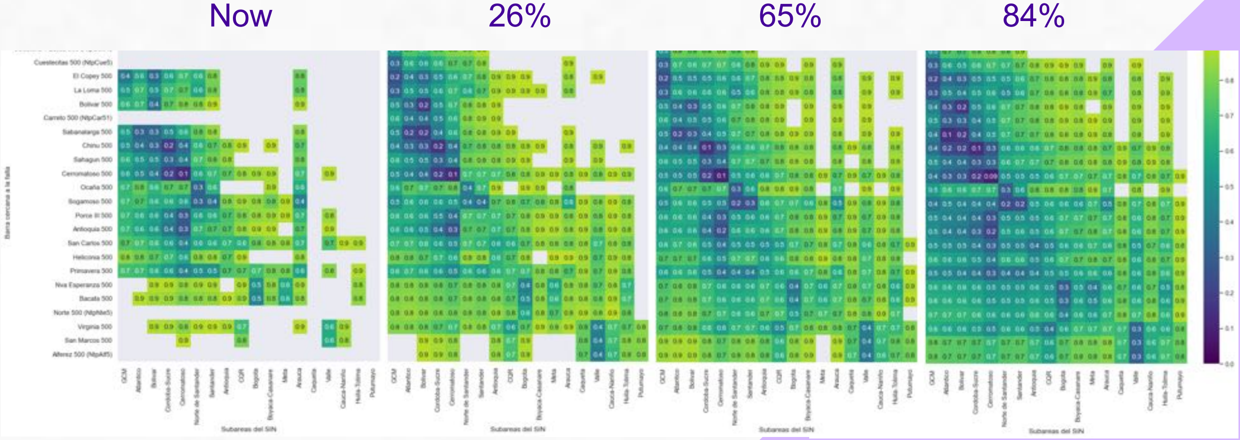
- ❑ Reduced levels of inertia
  - ➢ 300 MW contingencies might cause the UFLS scheme to operate. Required inertia of 30 – 40 GVAs.
  - ➢ Expected higher RoCoF (up to 1 Hz/s)

- ❑ Reduced grid strength
  - ➢ Deeper voltage sags
  - ➢ Increase spread of voltage sags in the grid
  - ➢ Fault Induced Delayed Voltage Recovery (FIDVR)
  - ➢ N-1 might cause the UFLS scheme to operate

- ❑ Reduced levels of reserve for primary response







* Voltajes promedio en cada área de la red de 115-500 kV calculados a partir del método de cortocircuito completo. Aporte inicial de cortocircuito en los inversores de acuerdo al modelo FSC.

Transmission

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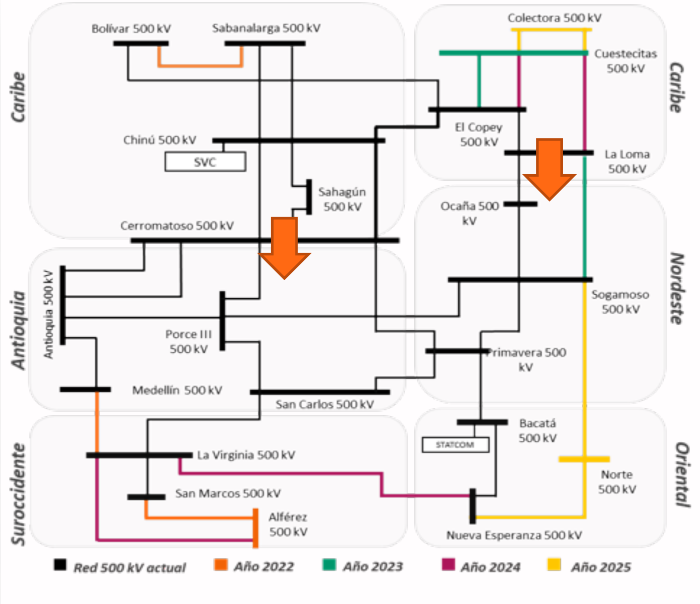
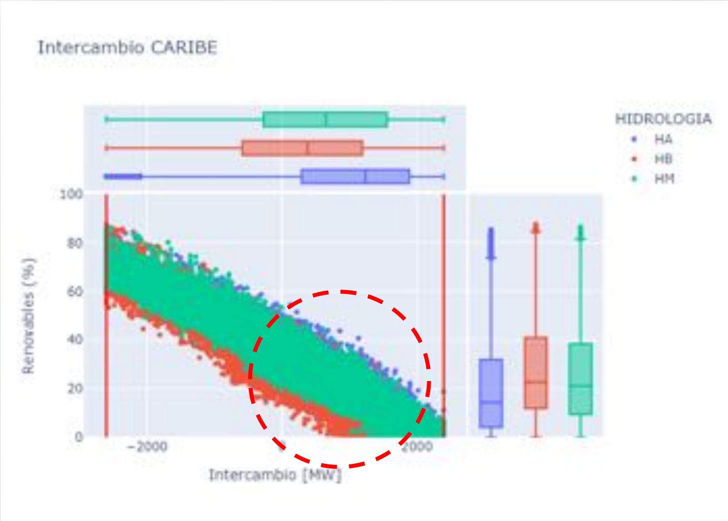
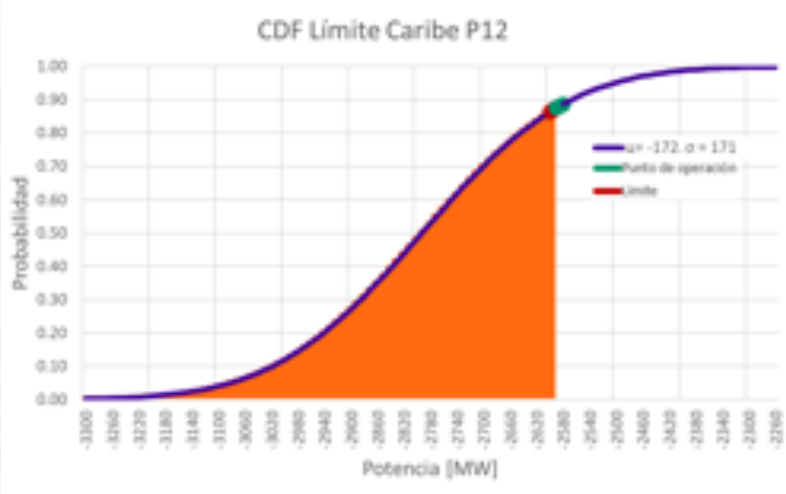
- For the **export limit**, complementary works are necessary in the northern networks to evacuate the expected generation capacity (from FERNC and THERMAL sources) in these regions, especially in scenarios of low hydrology.
- In the event of a decrease in the capacity of the transmission lines to the EASTERN and SOUTHWESTERN regions due to unavailability or delays in the implementation of projects, limitations may arise in the system's ability to evacuate renewable generation from the northern part of the country to the load centers.







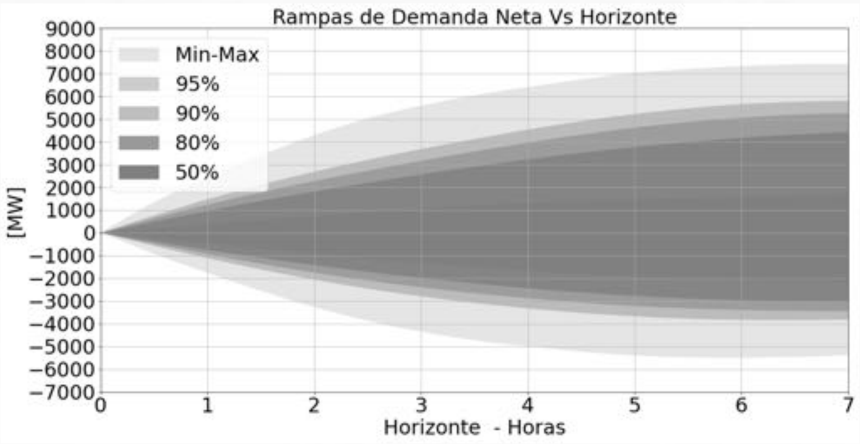
Flexibility

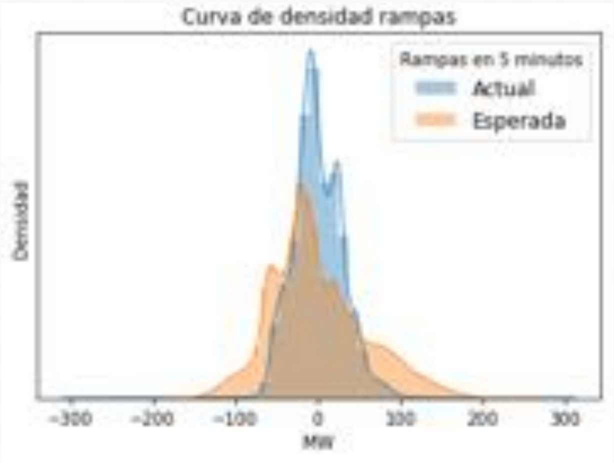
Wind and solar curtailment in conditions of low net demand (less than 4000 MW):

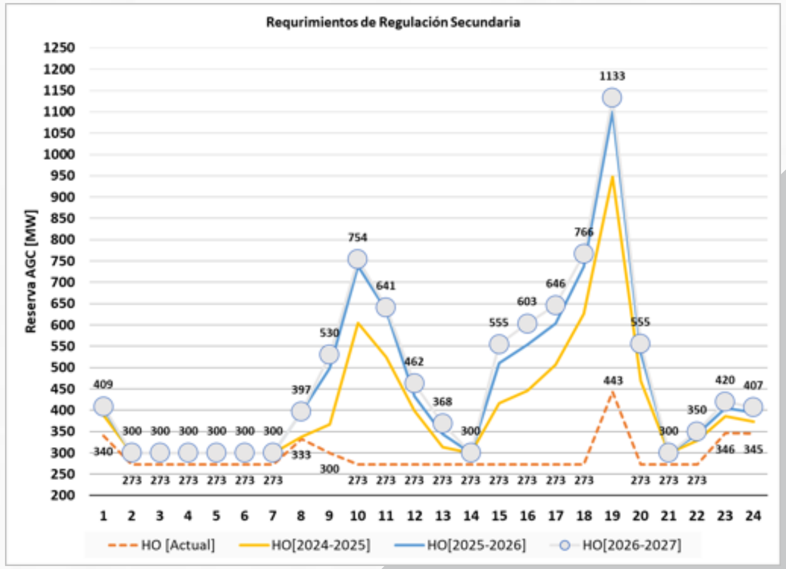
- It is recommended to advance in the flexibility of the available thermal and hydraulic park.

New regulatory and technological elements of operational coordination would be required in the short term to maintain the balance between load and generation:

- Unit Commitment with less granularity and closer to the real time operation.
- Shorter operational coordination times to raise or lower generation, through power instructions sent digitally to generators.
- Regulatory incentives for demand and generation to adjust their production and consumption expectations.
- Regulatory incentives to improve system observability (load and generation) as well as the quality of measures available in actual operation.







Sufficiency

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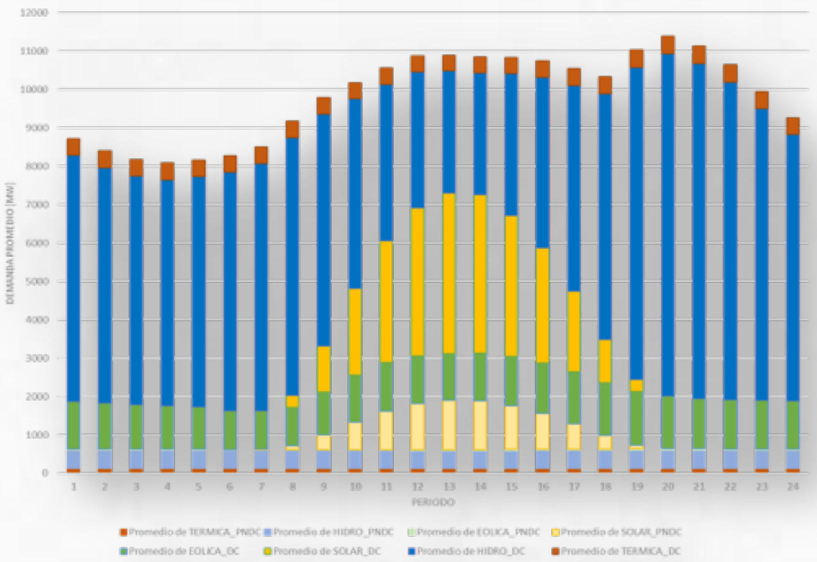
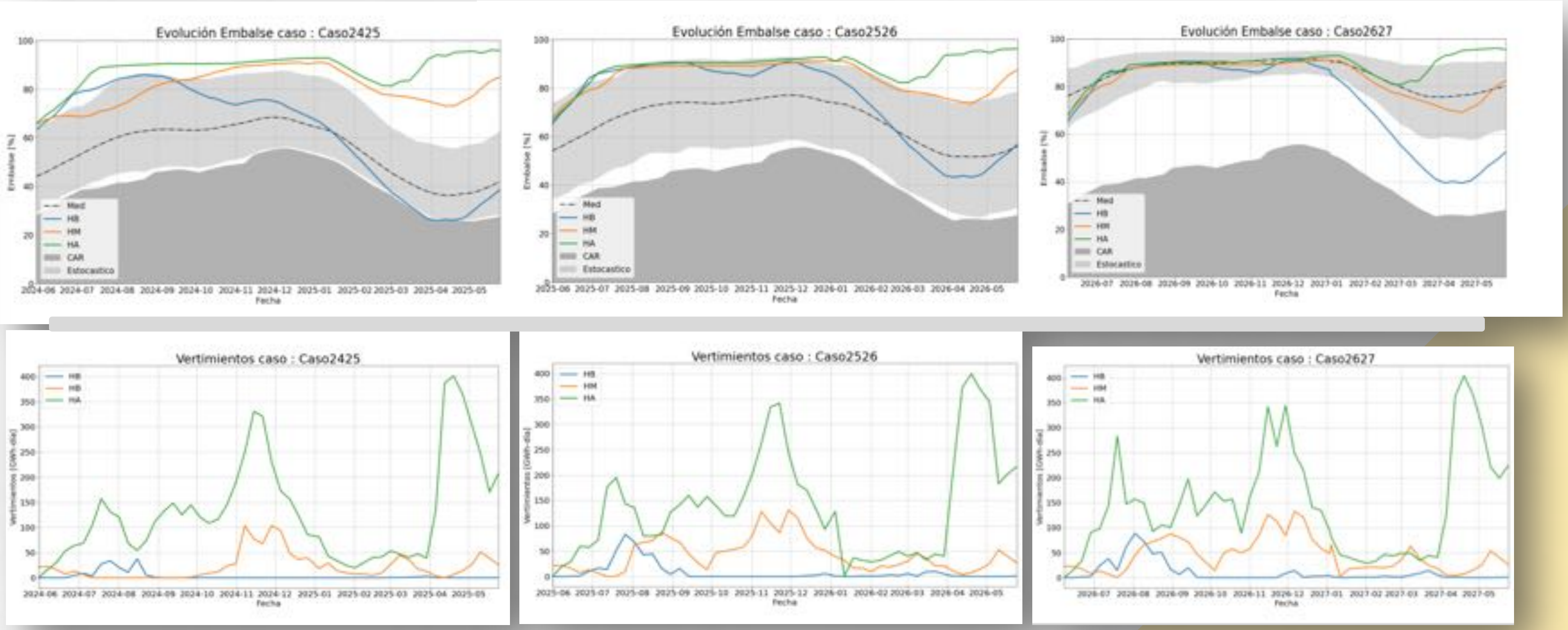
Simulations show that the System has the necessary energy sufficiency for 2024 – 2027 because:

- The demand considered is fully met.
- A reliable behavior is found in the system's hydric reserves.
- It is observed that in times of shortage of solar, wind or water resources, the thermal park responds to the needs of reliability and safety of the system.

Improve national systems for measuring, analyzing and predicting meteorological variables, as well as alert systems for anomalies of these variables that may affect solar and wind energy production and generate risk conditions for energy sufficiency.





There is still work to do…

XM needs:

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- Construction of the road map for XM energy transition to renewables:
- Improve the generation and load forecast.
- Incorporate dispatch programs with lower granularity than hourly.
- Analyze more planning scenarios in shorter time.
- Appropriately damped local and inter-area oscillations
- Services of short-circuit level contribution and inertia contribution, as well as the minimum levels of network strength and acceptable voltage dip propagation for the system.
- Develop of RMS and EMT models and analyses.
- Improve system observability
- ….

Thank you

Sumamos energía,
sumamos pasión

Thank you

Sumamos energía,
sumamos pasión

GLOBAL PST CONSORTIUM

VIETNAM

A SYSTEM IN RAPID TRANSITION

Bui Duy Linh

EVN - National Load Dispatch Centre

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VIETNAM
A SYSTEM IN RAPID TRANSITION

Bui Duy Linh
EVN - National Load Dispatch Centre

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nationalgridESO

NREL Transforming ENERGY

IEEE Advancing Technology for Humanity

VTT

AEMO AUSTRALIAN ENERGY MARKET OPERATOR

CSIRO

EPRI ELECTRIC POWER RESEARCH INSTITUTE

EIRGRID GROUP

Imperial College London

Fraunhofer CINES

DTU

olade Organización Latinoamericana de Energía

ercot

ESIG ENERGY SYSTEMS INTEGRATION GROUP

California ISO

CSIR Touching lives through innovation

ENERGINET

ASEAN CENTRE FOR ENERGY ACE

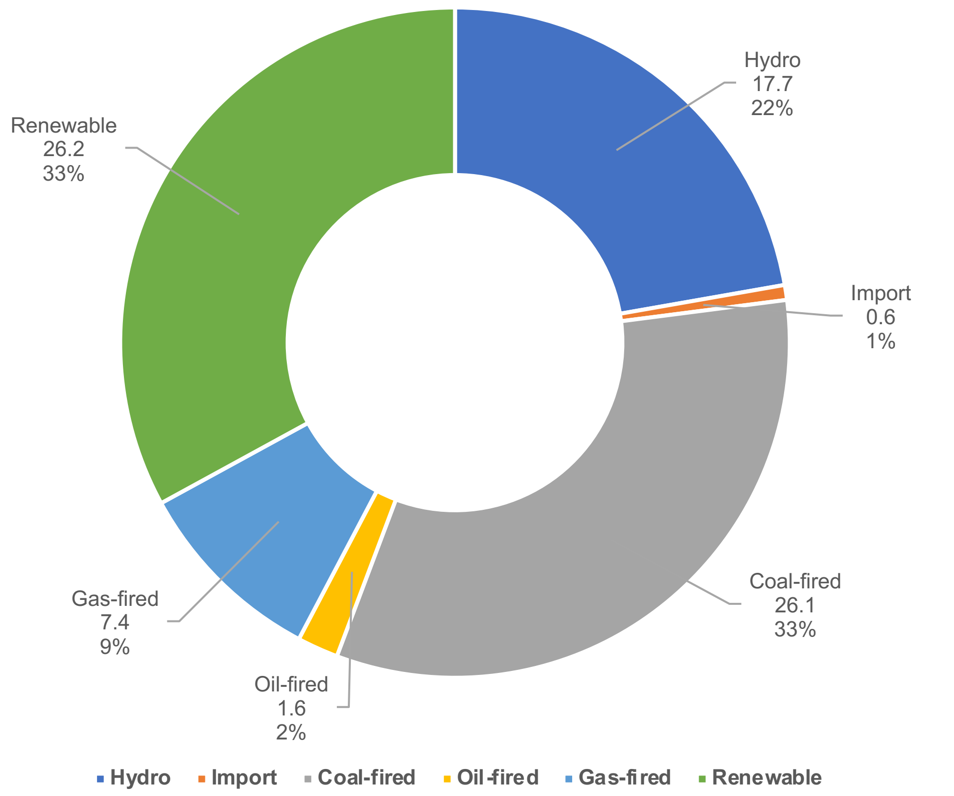
VIETNAM POWER SYSTEM

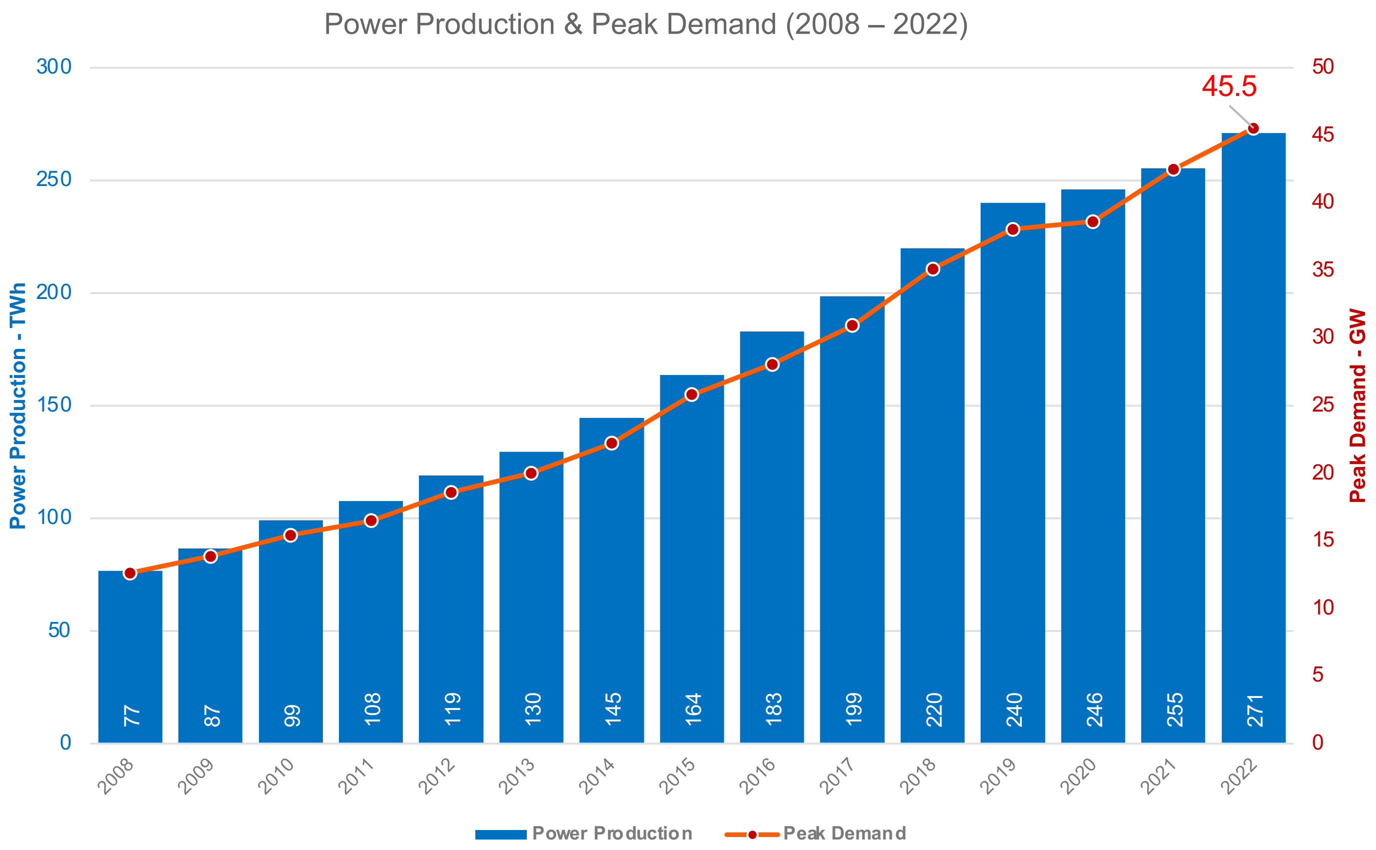
Supply & Demand

79.5 GW (Installed Capacity)

45.5 GW (Peak Demand)

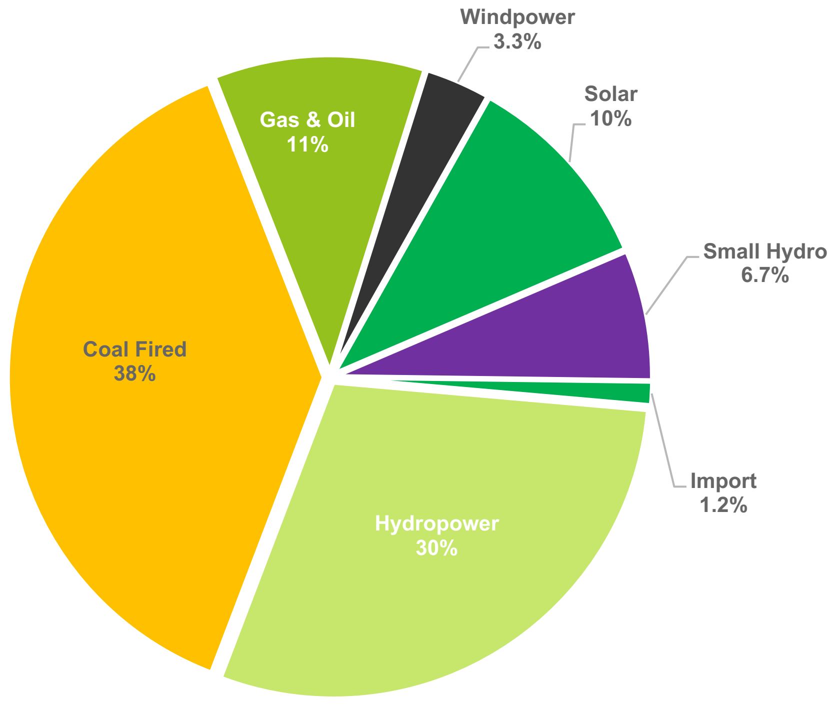
271.1 TWh (Total Power Production)





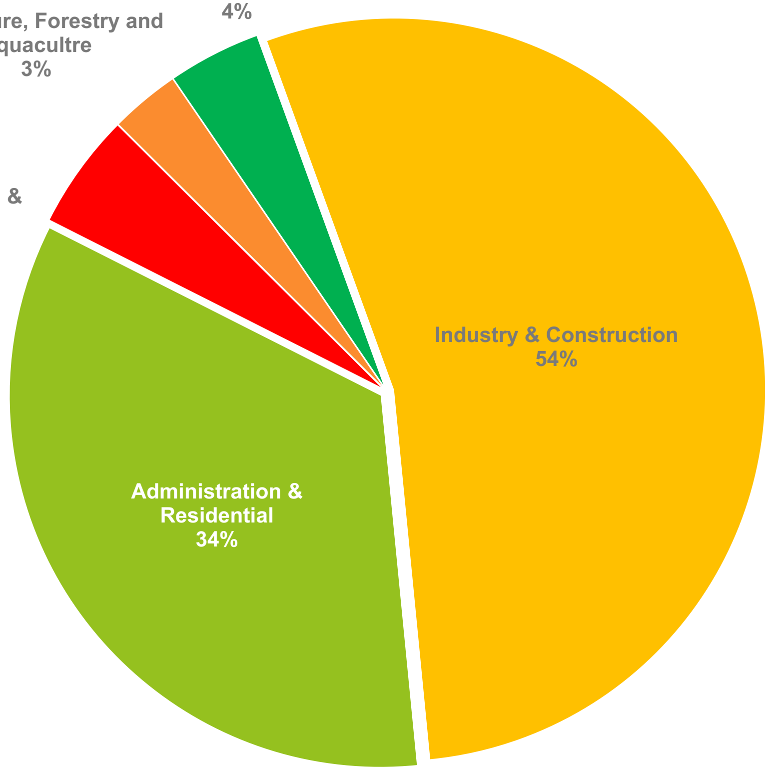
Power Production Mix - 2022

Type	Production (TWh)	Shared (%)
Coal Fired	104.54	38%
Hydropower	80.35	30%
Gas & Oil	29.47	11%
Wind	9.04	3.3%
Solar	28.39	10%
Small Hydro	18.19	6.7%
Import	3.23	1.2%



Consumption Mix - 2022

Type of consumer	Share (%)
Industry & Contrustion	54 %
Administration & Resident	34 %
Commercial & service	5 %
Agriculture, Forestry and Aquacultre	3 %
Other	4 %

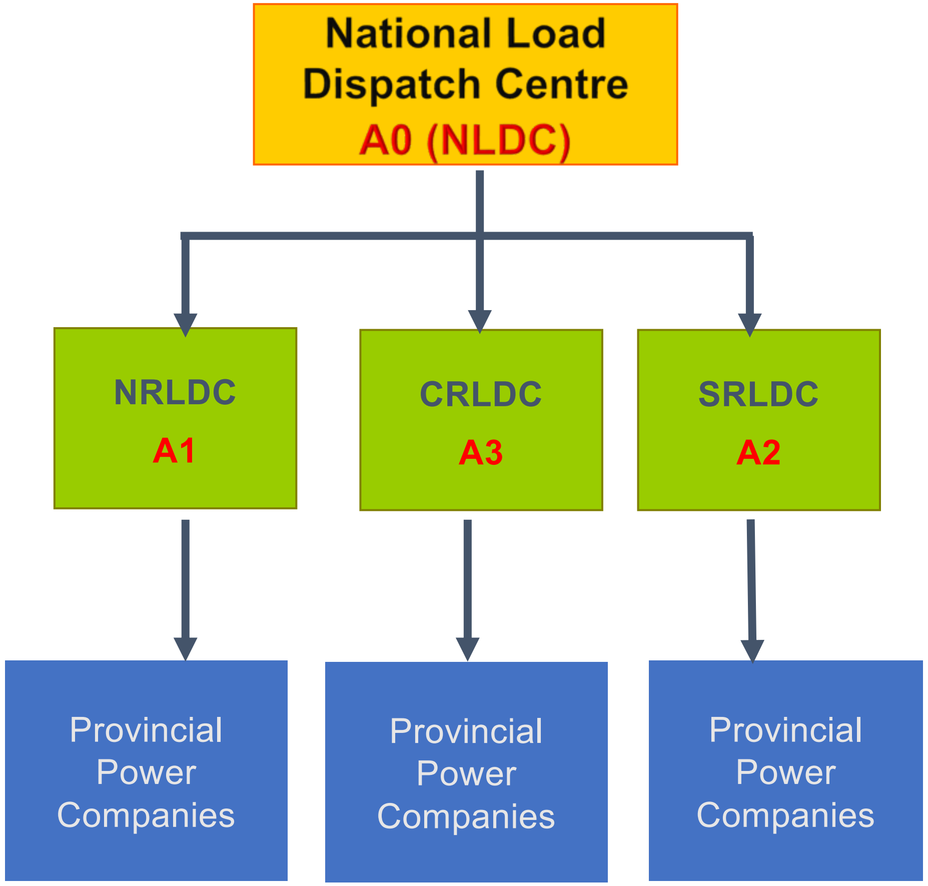


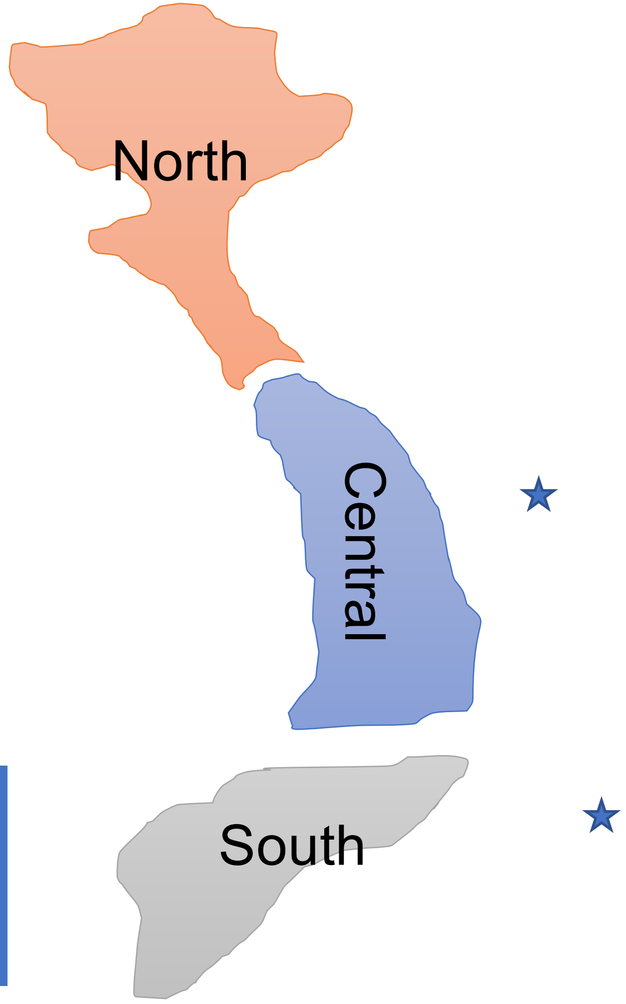
Dispatching Hierachy

Nation Level:
500 KV Grid,
Plant >30 MW

Region Level:
220 KV Grid,
Plant <=30 MW (connected Regional Grid)

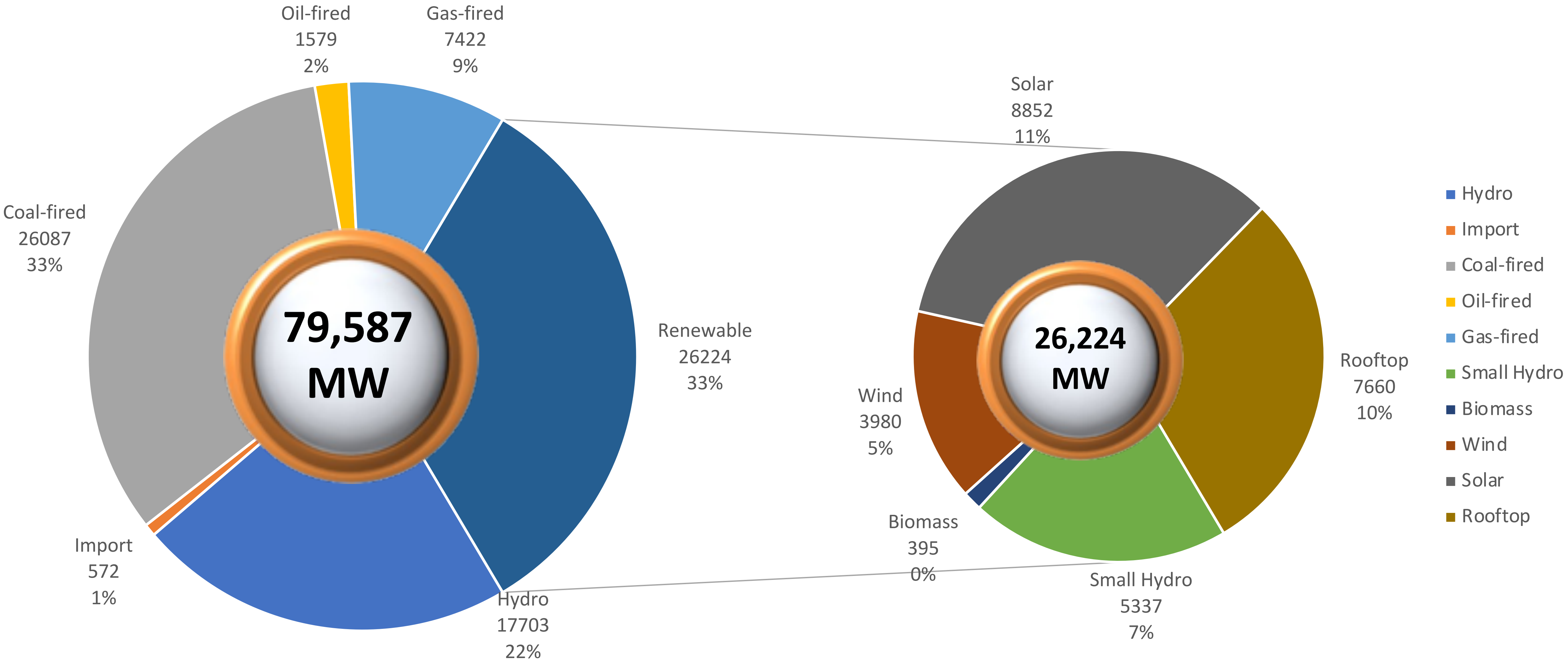
Distribution Level:
Medium/Low voltage Grid,
Plant <= 30MW (connected Distribution Grid)



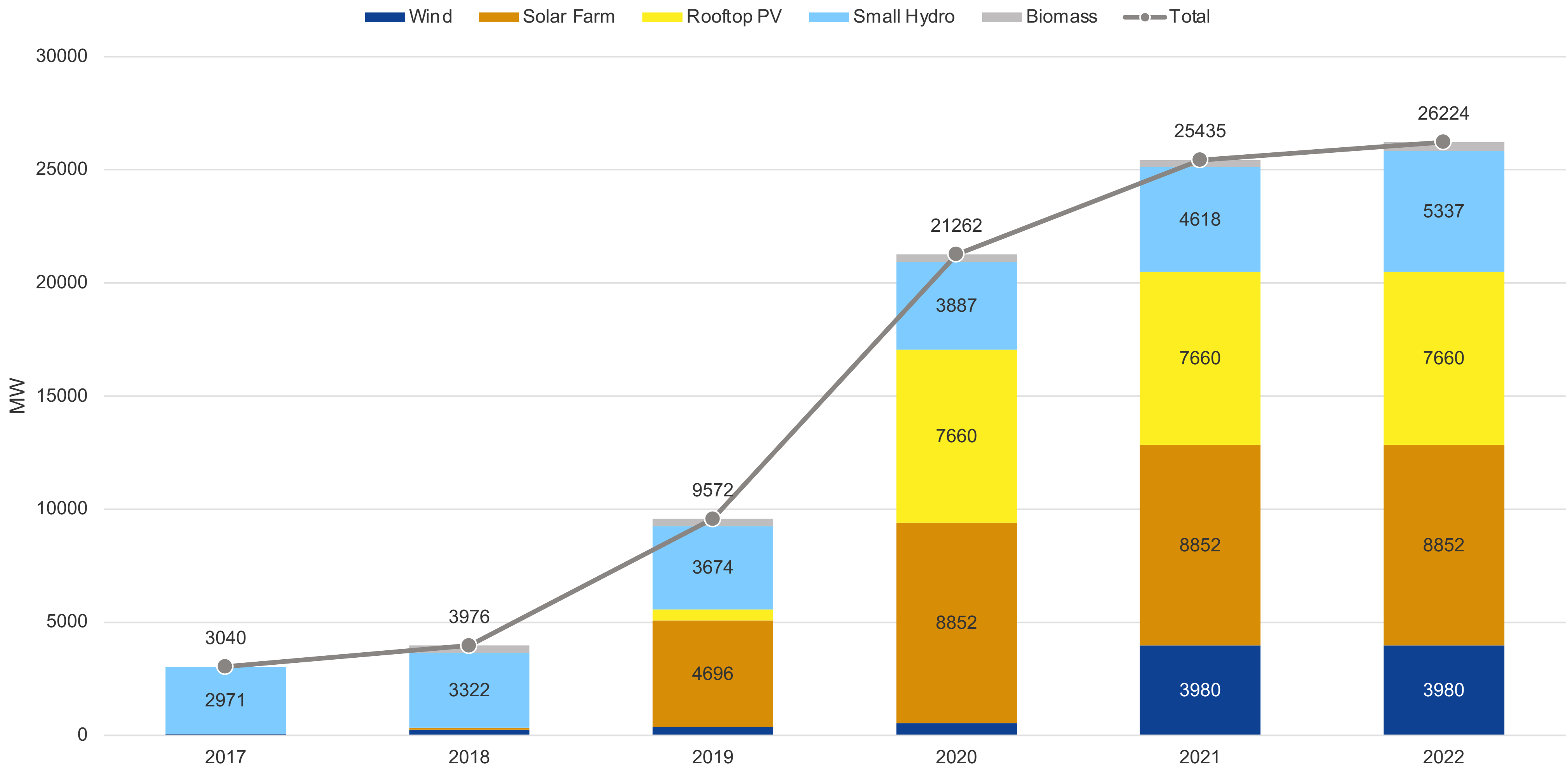


CURRENT STATUS OF RENEWABLE ENERGY

Renewable Installed Capacity



Renewable Installed Capacity

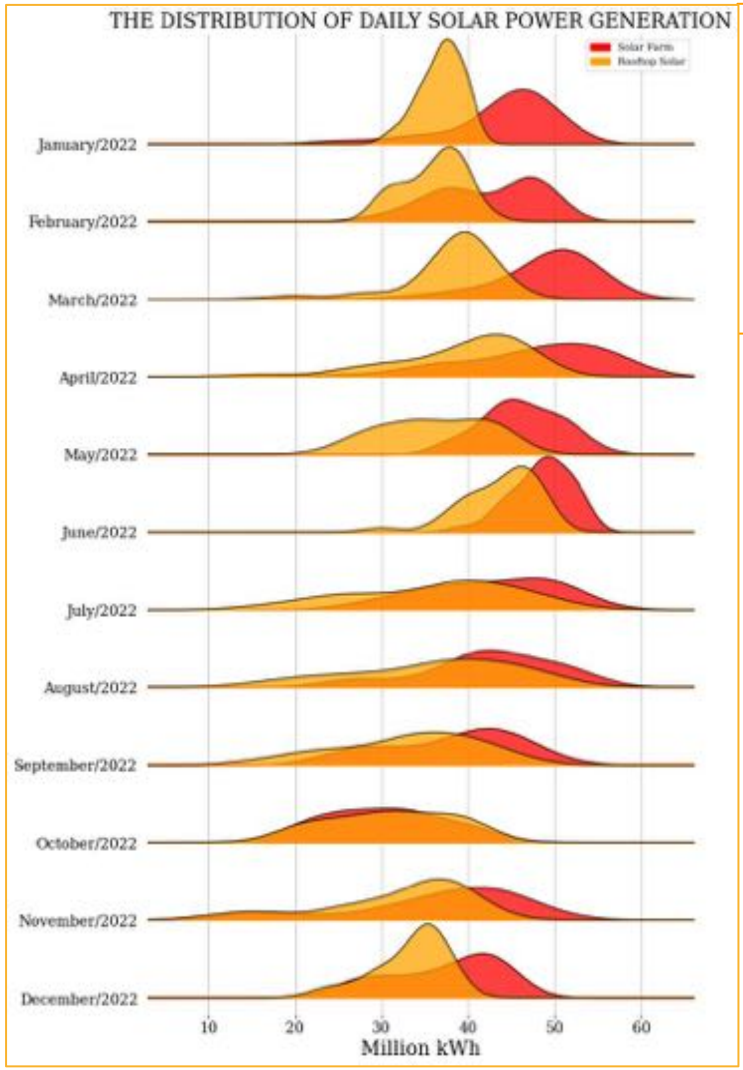


RENEWABLE ENERGY OPERATION

Challenges


Scheduling
Planning
Forecasting
Operational Challenges
Workload & Human resource
Congestion Management
Inertia Management

Planning

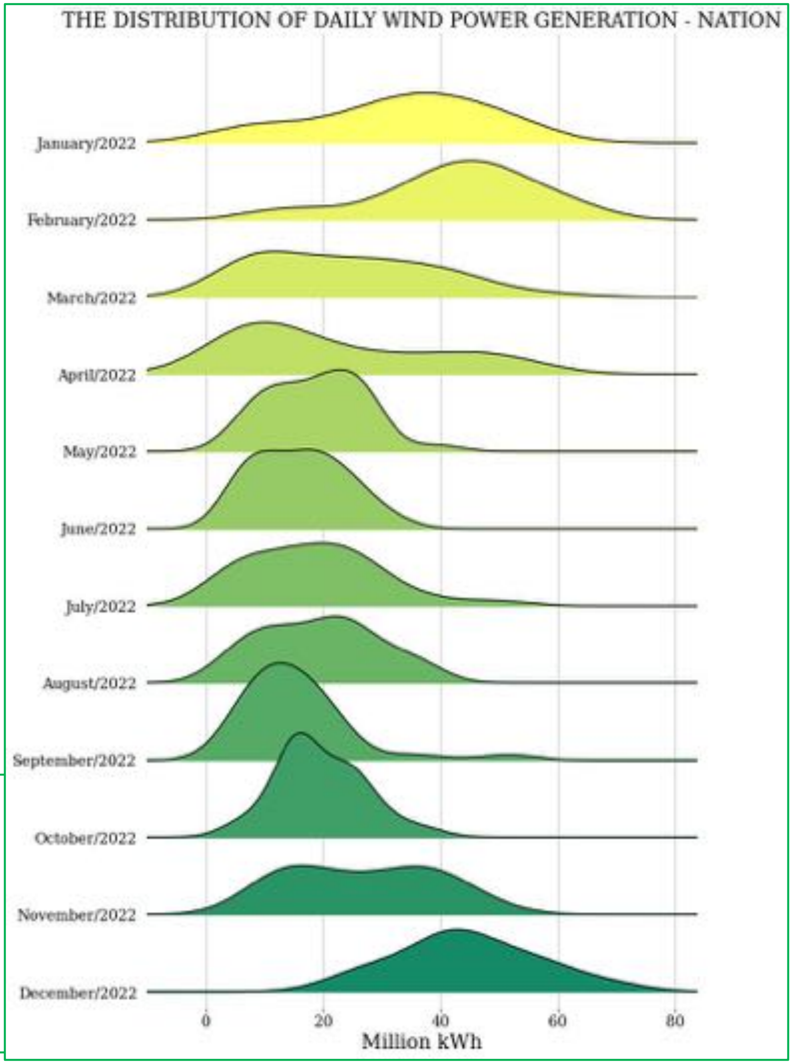


+ Daily solar farm generation: 15-55 mil.kWh
+ Daily rooftop PV generation: 10-50 mil.kWh
+ Good sunny months: Jan-June

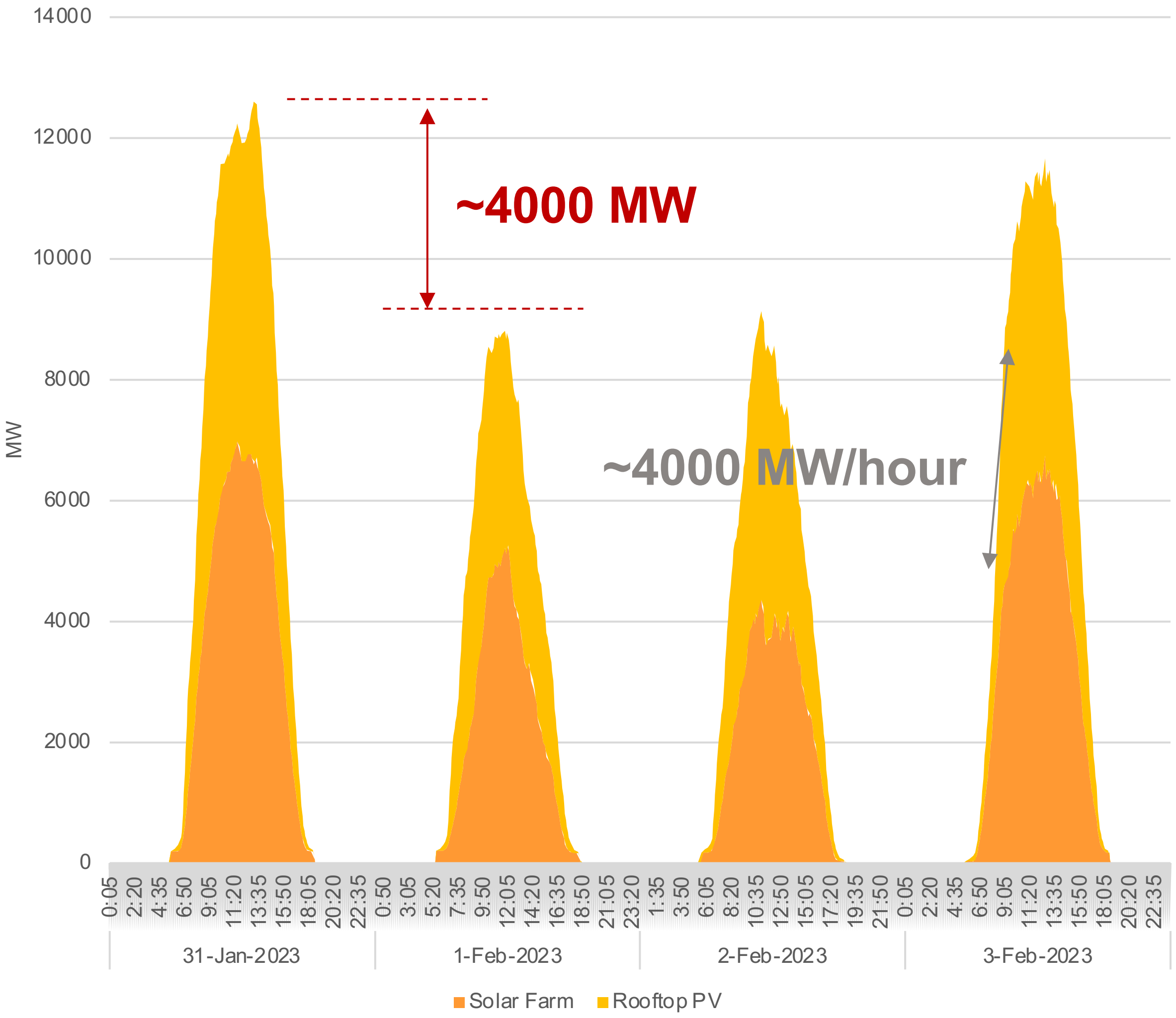
!!! Long term forecasting
⇒ Statistics
⇒ Probalistic Forecasting
⇒ Meteorological Data?

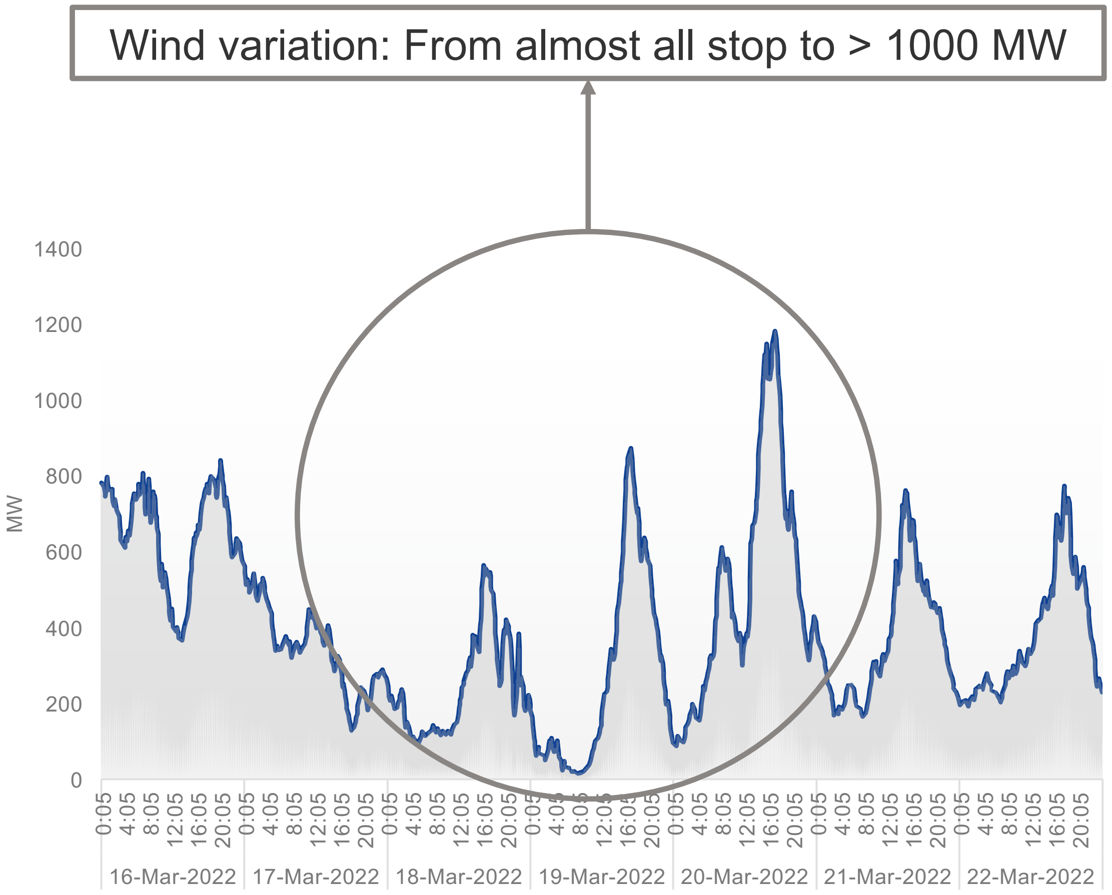
+ Daily wind farm generation: 7-70 mil.kWh

+ Good windy months: Dec - Feb



Scheduling – Daily Generation Profile

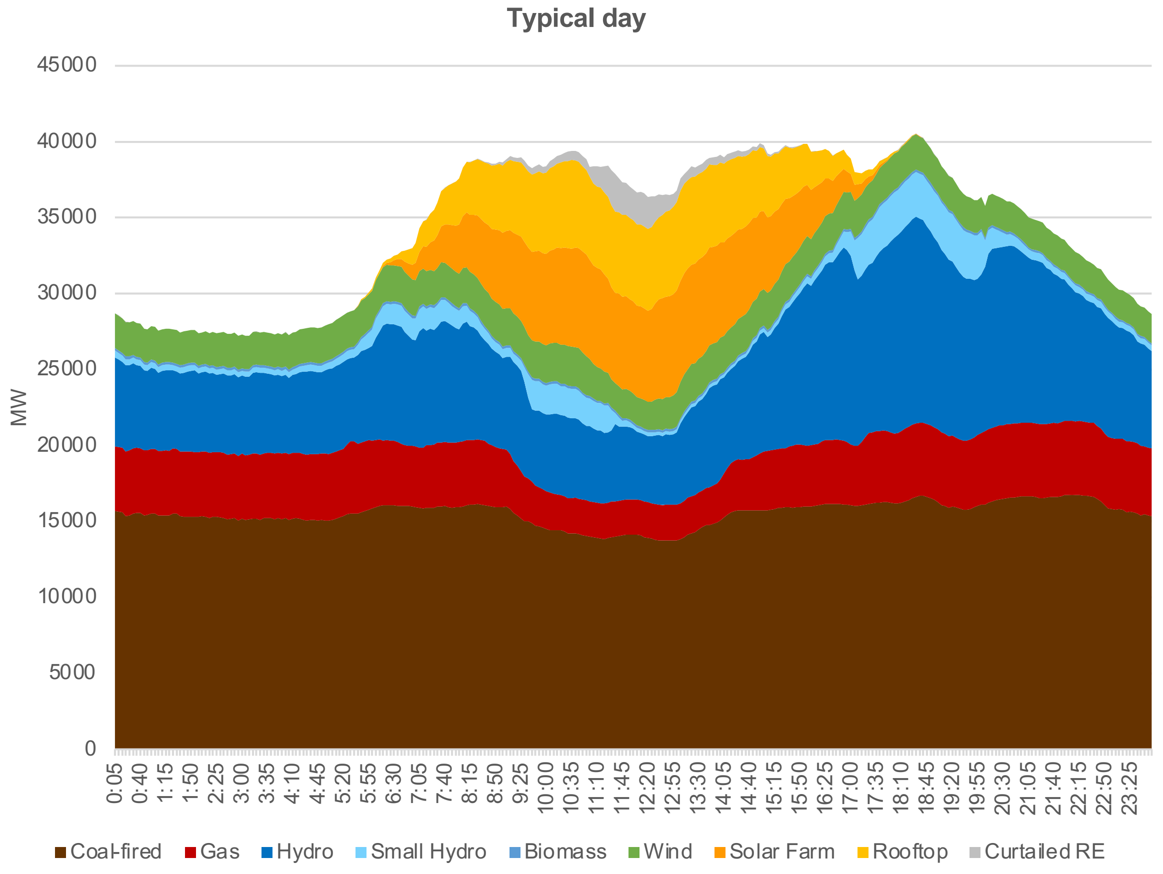


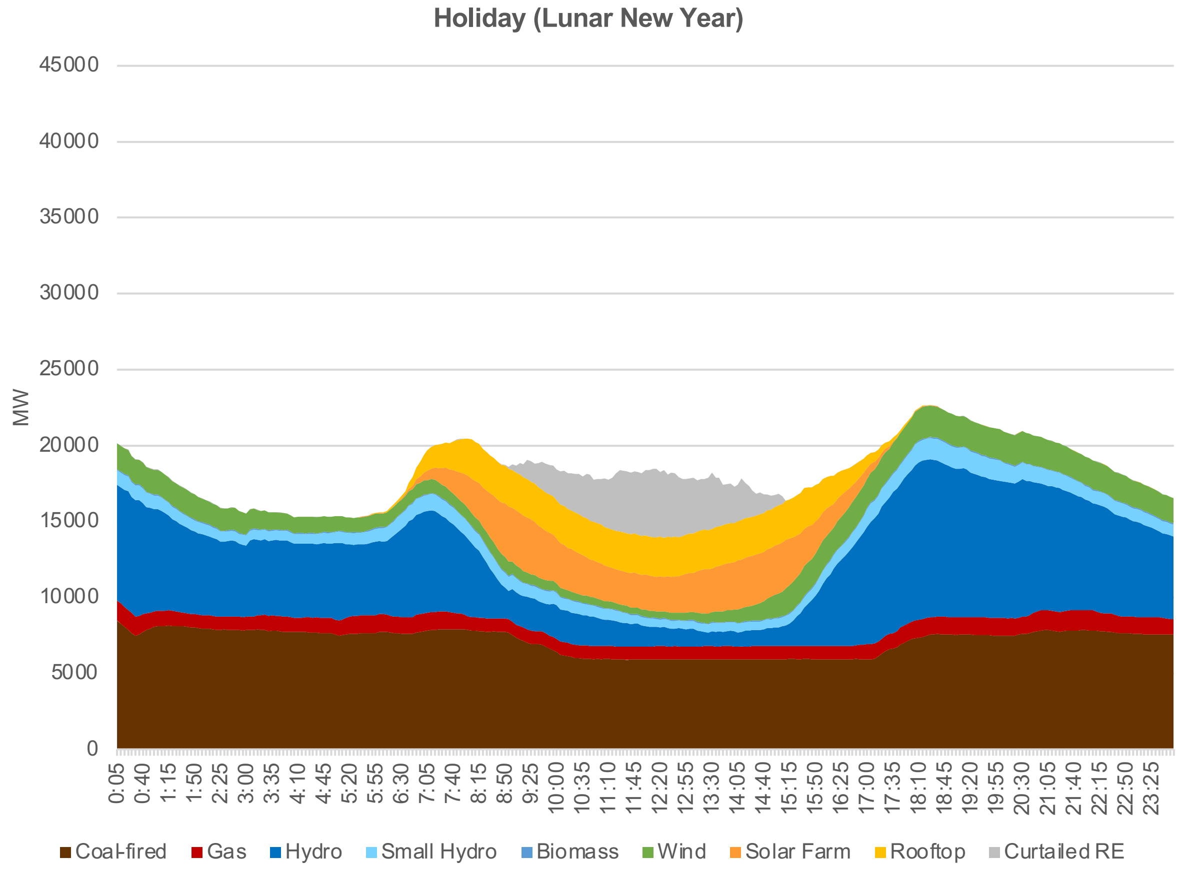


Scheduling – Daily Generation Profile

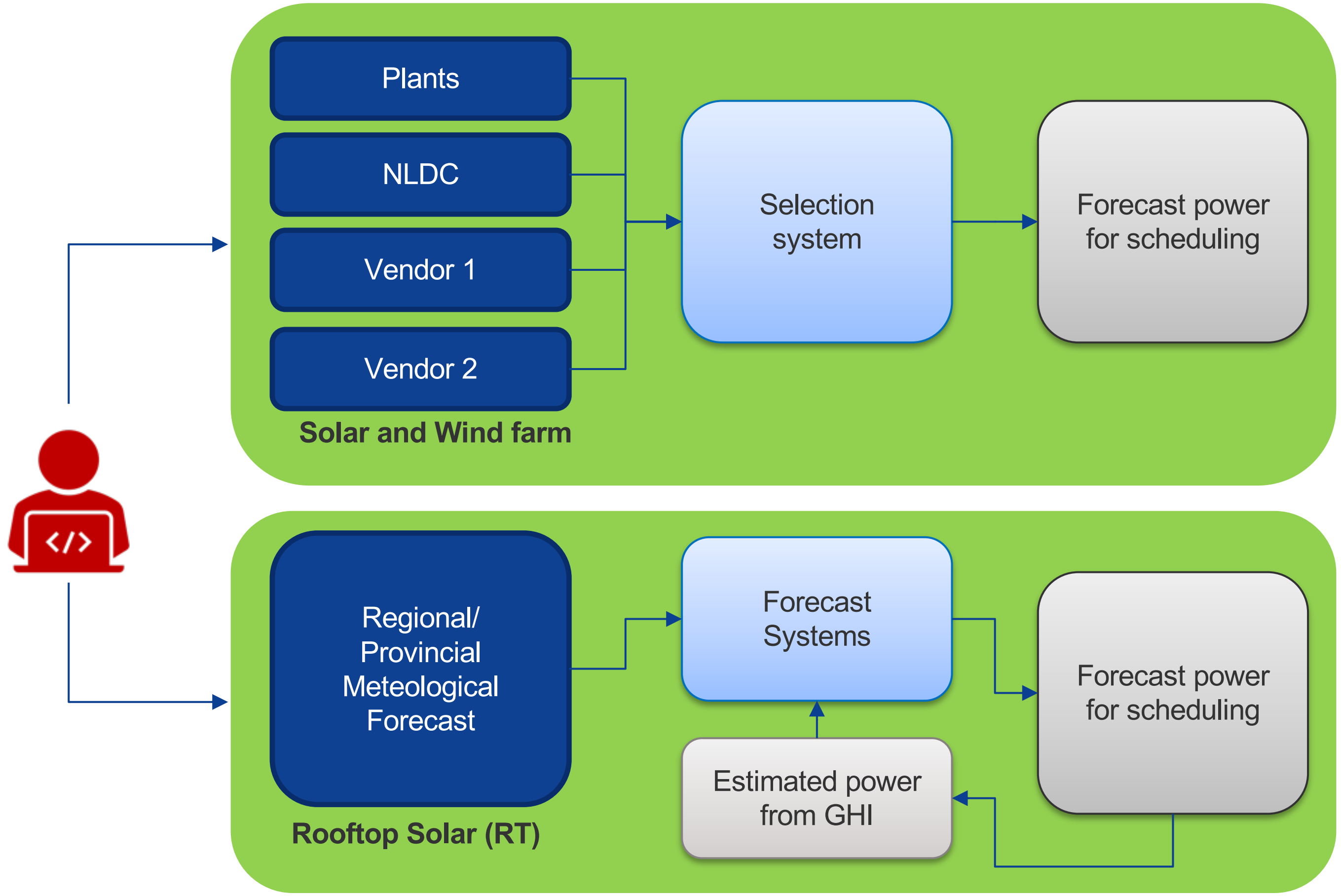
Optimize

- **Load forecasting**
- **RE forecasting**
- **Maintainance scheduling**
- **Reserve**





Renewable Short-term Forecasting



Forecast for wind & solar farm: resolution 15 minutes & duration 14 days:

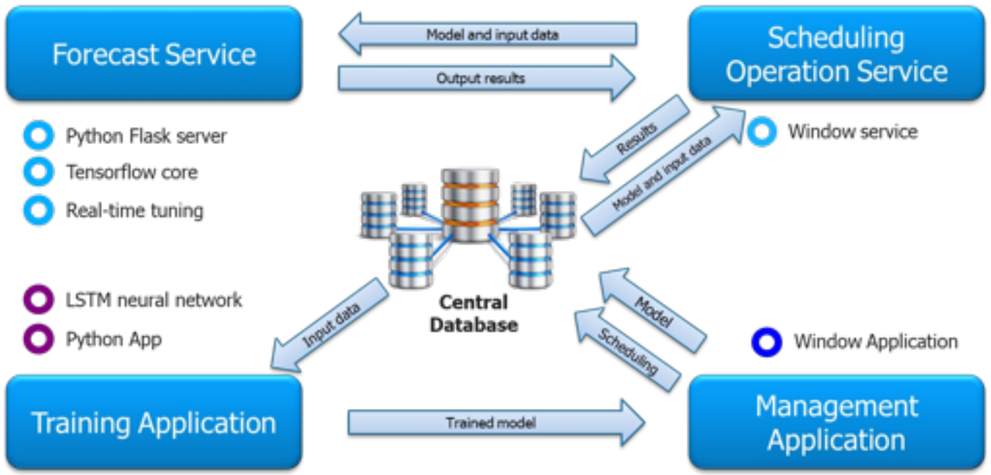
- 2 sources from international vendors
- 1 source from RE plants
- 1 in-house forecast sources developed by NLDC: Artificial Intelligent Models (LSTM)

Forecasting and Monitoring System for RT:

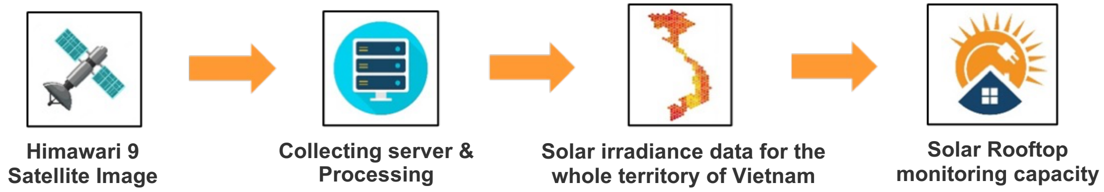
- Detailed for every 110kV substations
- Satelite image data (Himawari-9)
- Forecast length: up to 14 days
- Resolution: 15 mins
- Update frequency: 15 mins

Forecasting System

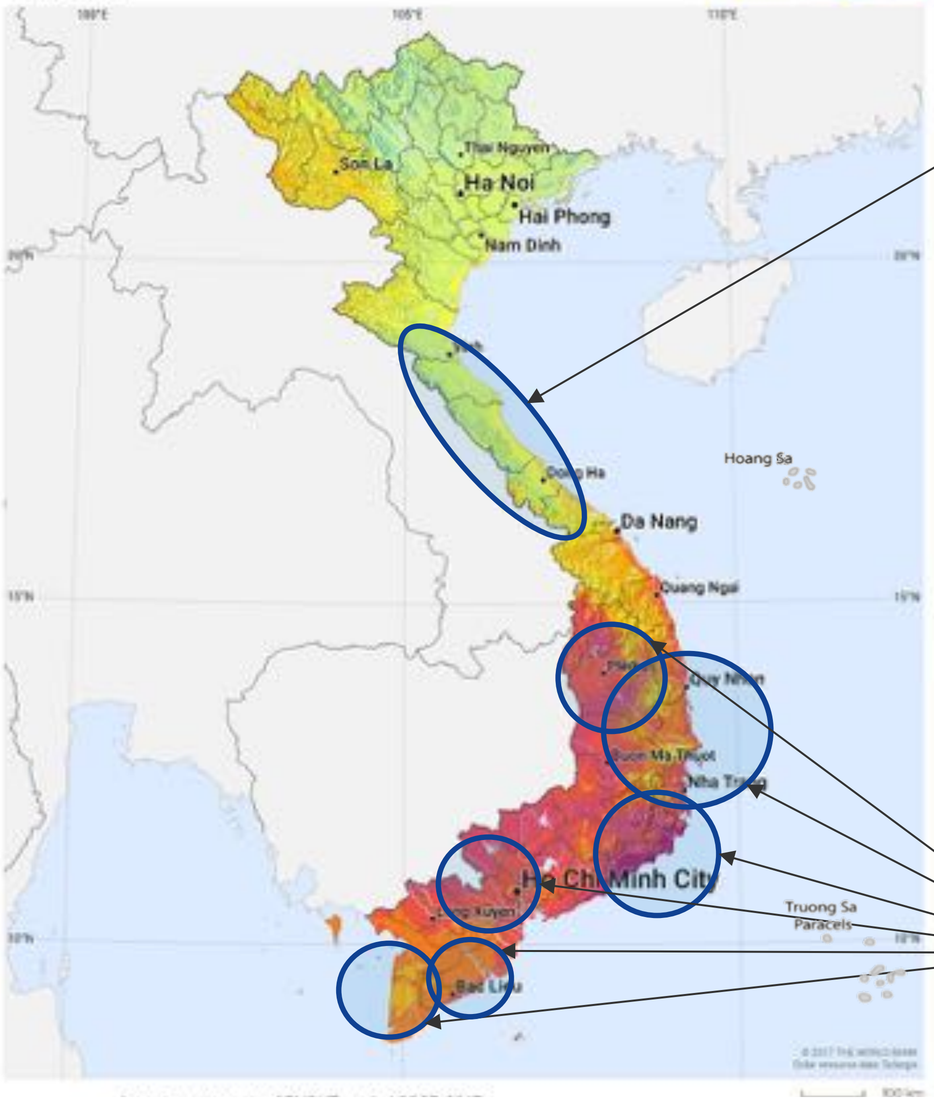
Solar & Wind Farm



Rooftop PV



Congestion Management



Inter-region congestion: 500kV lines of North-Central interface

Scheduling

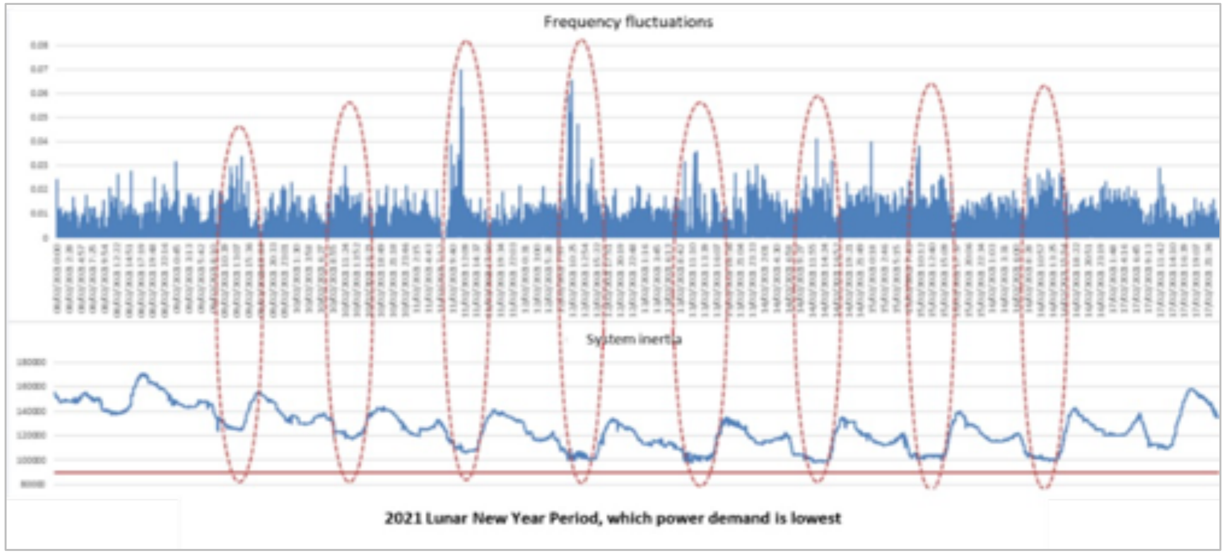
- Week-ahead curtailment allocation for rooftop PV
- Day-ahead curtailment allocation
- Intraday update curtailment allocation

Realtime

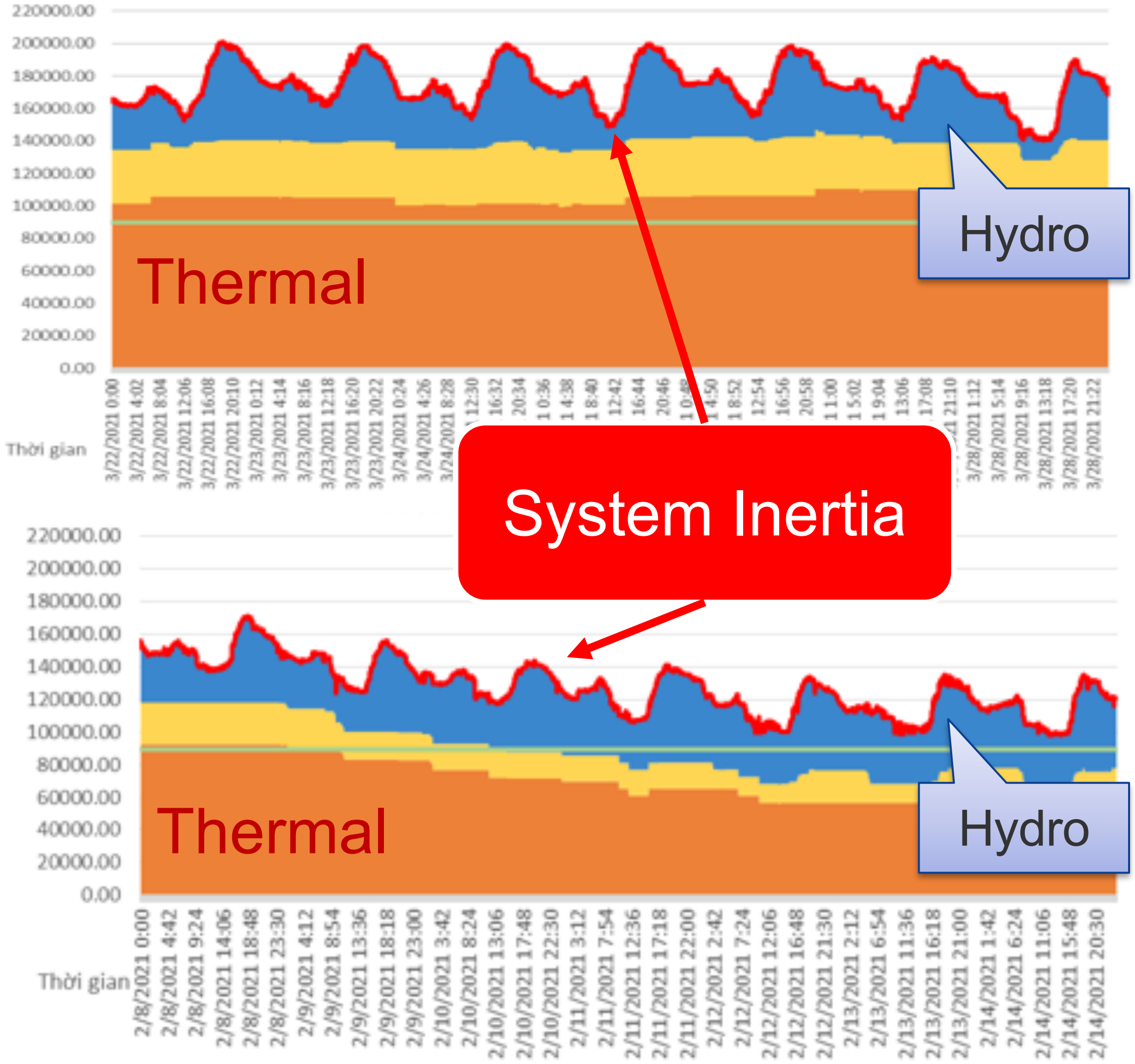
- Apply AGC for plants of congestion groups
- AGC: Automatic Generation Control

Local congestion: 220/110kV lines

Inertia Management



Real-time and minimum inertia values calculated were able **to assist System operators** in the critical days of system operation



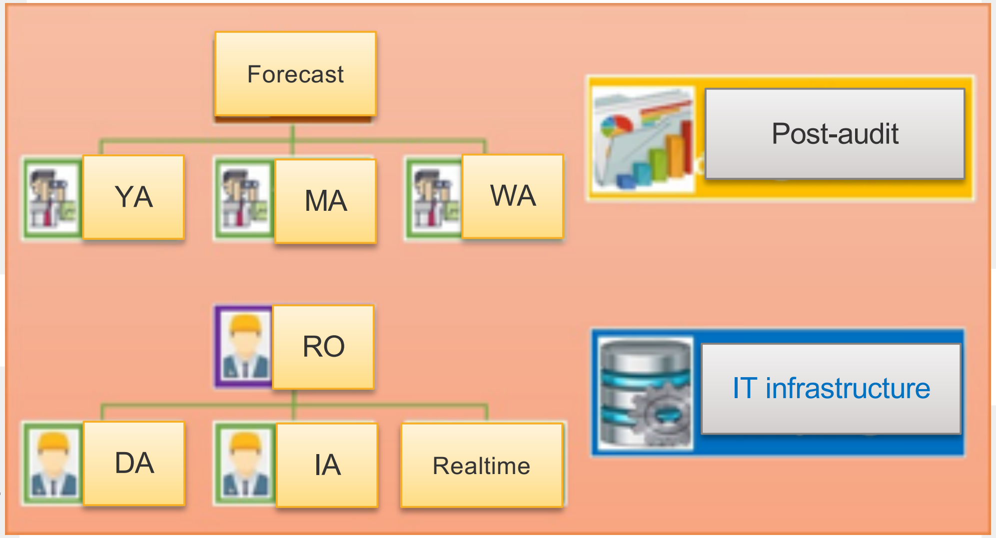
Workload & Human Resource

Forecast

- Build/ train/ update forecasting models,
- Forecasting renewable energy sources for year, month and week planning.
- Collect, analyze, calibrate and manage data for forecasting

Post-audit

- Implementation of renewable energy source operation reports
- Perform assessments and post-inspections according to timeframes and as required.
- Performance of contracts for the purchase of forecast data (Evaluation of errors, tabulation of periodic payments)



New Deparment:
Renewable Energy Opeartion Department

National Load Dispatch Centre

Renewable Operator

- Forecast of next day/next interval,
- Calculate and publish generating capacity for scheduling / next day / next interval / real-time,
- Calculation and disclosure of the value of allocated generating capacity due to grid limits
- Monitoring and operation of renewable energy sources
- Monitor the quality of forecasts from suppliers.

IT infrastructure

- Building tools to serve the needs of operating renewable energy sources
- Building, managing and exploiting database systems related to renewable energy sources
- Implementation of capital plan of investment

Thank You

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Q&A

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