System transformation for an optimised integration of renewable energies in Ukraine – Gap Analysis Report

Client: Ukrenergo

Country: Ukraine

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System transformation for an optimised integration of renewable energies in Ukraine – Gap-Analysis Report

Summary	This report presents the analysed gaps in the Ukrainian power system regarding the preparedness for Renewable Energy Sources (RES) integration identified by comparing with the German Best Practice. Further, the gaps are mapped with recommendations in order to enable a quick and efficient RES integration into the system.	
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Related documents

(1)	AS-IS Report (Version 3, 11.10.2019)
(2)	Workshop Reports (Workshop 1-5)

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List of Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
BRP/BSP	Balance Responsible Party/Balance Service Providers
CACM	Capacity Allocation and Congestion Management
CAPEX	Capital Expenditure
CEP	Clean Energy Package
CHP	Combined Heat and Power
CRM	Capacity Remuneration Mechanisms
DACF	Day-Ahead Congestion Forecast
DAM	Day-Ahead Market
DLR	Dynamic Line Rating
DSO	Distribution System Operators
EB	Energy Balancing
EGI	Elia Grid International GmbH
ENTSO-e	European Network of Transmission System Operators for Electricity
EU	European Union
FACTS	Flexible Alternate Current Transmission Systems
FiP	Feed-in-Premium
FiT	Feed-in tariff
FBMC	Flow-based Market Coupling
GL	Guideline
HVDC	High Voltage Direct Current
IPS	Integrated Power Systems
IT	Information Technology
KPI	Key Performance Indicator
NEMO	National Electricity Market Operator
NEURC	National Energy and Utilities Regulatory Commission
NREAP	National Renewable Energy Action Plan
PP	Power plant
PST	Phase-Shifting Transformers
PV	Photovoltaic
RES	Renewable Energy Sources
STATCOM	Static Synchronous Compensator
TSO	Transmission System Operator
RES	Renewable Energy Sources

1 Kurzfassung

Die Transformation des ukrainischen Stromsystems und die Herausforderungen der erneuerbaren Energien

Erneuerbare Energien (EE) stellen für die Ukraine eine große Chance dar, denn das Land besitzt ein hohes Potential an regenerativen Ressourcen. Darüber hinaus liegt die Ukraine in unmittelbarer Nachbarschaft zur Europäischen Union, was es ihr ermöglicht ein Exporteur von überschüssigem EE-Strom zu werden. Die kürzlich veröffentlichte "Vision für den Energieübergang in der Ukraine" zeigt, dass die ukrainische Regierung diese Chance erkannt hat, indem sie das Ziel einer Erhöhung des Anteils erneuerbarer Energien auf 70% bis 2050 in Verbindung mit einem Ausstieg aus der Kohle, einer Reduzierung der Kernenergieerzeugung auf 20-25 % und einer Energie-Marktintegration mit der Europäischen Union festgelegt hat. Dieser ehrgeizige Kurs begann bereits 2017 mit der Verabschiedung der Energiestrategie der Ukraine und der Unterzeichnung des Abkommens über die Bedingungen für den künftigen Verbund des ukrainischen Stromsystems mit dem kontinentaleuropäischen Stromsystem ENTSO-e. Die Ukraine strebt dabei eine Erhöhung der aus erneuerbaren Energiequellen und Wasserkraftwerken erzeugte Energie bis 2025 auf 11% und bis 2035 auf 25% an. Zudem erfordert die Verpflichtung zu den Zielen der Europäischen Union die Reduktion des CO2-Ausstoßes der Ukraine von 40% bis 2030, die Erhöhung des Anteils Erneuerbare Energien von mindestens 32% bis 2030 sowie den Ausbau des europäischen Energiehandels und die damit verbundene Bereitstellung von mindestens 70% der verfügbaren Transportkapazität der Grenzkuppelleitungen, wie es durch das Clean Energy Package (CEP) der Europäischen Union festgelegt wird. Diese Ziele stellen die Ukraine vor enorme Herausforderungen und erfordern eine radikale Umgestaltung des ukrainischen Stromsystems.

Derzeit dominieren fossile Brennstoffe den Energieerzeugungsmix in der Ukraine: Die Erzeugung aus Kernenergie liefert mehr als 50% des Stroms, gefolgt von Kohle mit Anteil von ca. 30%; Erdgas wird dabei hauptsächlich in Kraft-Wärme-Kopplungsanlagen (KWK) für Fernwärmezwecke verwendet. Die gesamte Erzeugungskapazität in der Ukraine erreicht derzeit 49,7 GW, wobei der höchste Anteil mit 60% auf Kohle- und 25% auf Kernkraftwerke entfällt. Diese Großkraftwerke wurden in der Nähe der Lastzentren im Norden und Westen der Ukraine errichtet. Die Wasserkraft stellt mit 6-7% den bedeutendsten Beitrag der aus Erneuerbaren Energien erzeugten Strommengen. Die übrigen Anteile tragen derzeit etwa 2% der erzeugten Energie bei. In der Energiestrategie für 2017 ist ein Anstieg der Erzeugung aus Wind- und Sonnenenergie mit einer installierten Leistung von 4500 MW bis 2025 vorgesehen. Bemerkenswert ist, dass dieses Ziel bereits Ende 2019 erreicht wurde und die Anträge auf Netzanschluss in Höhe von 11000 MW das Ziel von 2025 deutlich übertreffen. Diese Zahlen stehen für eine hohe Geschwindigkeit, aber auch eine hohe Unsicherheit der Entwicklung der Erneuerbaren Energien in der Ukraine.

Die Planung einer optimalen Entwicklung des zukünftigen Energiesystems unter dieser Unsicherheit ist eine große Herausforderung für Ukrenergo, und der steigende Anteil erneuerbarer Energien erfordert ein radikales Transformationssystem:

1. **Netzentwicklung:** Aufgrund des geographischen höheren EE-Potenzials wird voraussichtlich ein großer Teil der EE-Anlagen im südlichen Teil des Landes errichtet werden; die erzeugte Energie muss daher in die nördlichen und westlichen Gebiete transportiert werden. **Die resultierenden Stromflüsse werden zu zunehmenden Netzüberlastungen im Übertragungsnetz führen**, die durch Netzausbau gelöst werden sollten.

2. **Systembilanz**: Die steigende EE-Einspeisung erhöht die Variabilität im System (steilere Gradienten der Erzeugung) und die damit verbundene planerische Unsicherheit (Prognosefehler). Ferner wird der hohe Anteil an unflexibler Erzeugung aus konventionellen Kraftwerken **zu einem steigenden Bedarf an flexiblen Erzeugungsanlagen für die Bilanzierung des Systems führen**. Um die Betriebssicherheit zu gewährleisten, sollten neue Ansätze zur Gewährleistung der Systembilanz zum Einsatz kommen.

3. **Verteilte Erzeugung**: Kleine bis mittelgroße EE-Anlagen werden an den Spannungsebenen des Übertragungs- und vor allem Verteilnetzes angeschlossen. Diese Veränderung wird sich deutlich auf die Systemarchitektur auswirken, und Ukrenergo wird mit schwankenden Stromflüssen, aber auch mit Stromflüssen aus dem Verteilnetz in Richtung Übertragungsnetz umgehen müssen. **Der zukünftige Systembetrieb erfordert daher neue Systeme der Steuerung sowie des Datenmanagements**, um die große Anzahl der räumlich verteilten EE-Anlagen in den unterlagerten Spannungsebenen technisch zu steuern.
4. **Systemstabilität**: Mit steigendem Anteil von EE-Anlagen, die technisch durch einen Wechselrichter mit dem Stromnetz verbunden sind, müssen Energiesysteme neue **Herausforderungen einer zunehmenden nicht-synchronen Energieerzeugung** bewältigen, darunter fallen insbesondere fehlende rotierende Schwungmassen aus Großkraftwerken, eine erhöhte Sensibilität der Frequenz auf Bilanzabweichungen sowie Probleme mit der Spannungshaltung, niedrigeren Kurzschlussniveaus und der dynamischen Stabilität von Erzeugungsanalagen. Daher sollten erprobte sowie neu Netztechnologien (z.B. HVDC, FACTS) zum Einsatz kommen, die eine ausreichende Stabilität des Systems gewährleisten, vor allem bis eine ausreichende Synchronisierung mit dem europäischen Verbundsystem erfolgt ist.

Diese Systemtransformation wird alle Verantwortungsbereiche von Ukrenergo betreffen, wobei die wesentlichen Aufgaben der beschleunigte Netzausbau, der Verbund mit dem europäischen Verbundnetz ENTSO-e und die Errichtung eines funktionierenden Marktes für Systemdienstleistungen sind. Die Analyse dieser Herausforderungen bildet den Kern dieses Projektes.

Wesentliche ‚Gaps‘ für eine zuverlässige und nachhaltige Integration erneuerbarer Energien in das Übertragungsnetz der Ukraine

Im Rahmen des Projekts wurden fünf Experten-Workshops durchgeführt, welche die in Abbildung 1 dargestellten fünft Themenschwerpunkte abdecken. Die Diskussion der wichtigsten Erkenntnisse aus 20 Jahren EE-Integration in Deutschland ermöglichte es, unter Berücksichtigung der gegenwärtigen Situation in der Ukraine die jeweiligen Herausforderungen zu identifizieren.

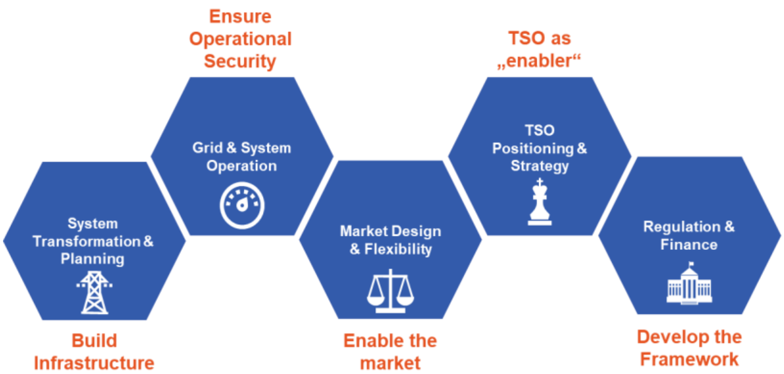

Abbildung 1 – Übersicht der fünf Themenschwerpunkte der durchgeführten Workshops

The bottom-up gap identification was further synthesized to the present gap analysis report, identifying the opportunities and optimization potential for Ukrenergo, and lately the challenges to integrate RES in Ukraine in a sustainable and secure way. The <u>key gaps</u> from the TSO perspective are mapped according to the five building blocks:

Ausgehend von einer Analyse der gegenwärtigen Situation wurden mit den Ergebnissen der Workshops die Gaps erarbeitet. Dadurch konnten die Chancen und das Optimierungspotenzial der Ukraine sowie die Herausforderungen für eine Integration erneuerbarer Energien in der Ukraine für eine nachhaltige und sichere Energieversorgung ermittelt werden. Die wichtigsten Gaps aus Perspektive des Übertragungsnetzbetreibers lassen sich entsprechend der fünf Themenschwerpunkte zusammenfassen:

1. ***Systemtransformation & Planung: Entwicklung der einer durch Erneuerbare Energien geprägten Netzinfrastruktur:***
    - Anwendung von **Methoden der szenariobasierten Netzplanung**, die auf die Besonderheiten der Ukraine zugeschnitten sind, um eine optimale und robuste Entscheidungsfindung unter den hohen Unsicherheiten, die das derzeitige Umfeld kennzeichnet, zu ermöglichen
    - Entwicklung von Entscheidungsprozessen bezüglich der Infrastrukturentwicklung einschließlich **erforderlicher Daten, Werkzeuge und Prozesse einer optimalen Netzplanung**
    - **Harmonisierung der ukrainischen Netzcodes** mit den Anforderungen von ENTSO-e
    - Entwicklung einer **langfristigen Strategie für die Entwicklung von Verbindungsleitungen mit den EU-Ländern** für den grenzüberschreitenden Handel und die gemeinsame Nutzung von Netzreserven
    - Zunehmende Bedeutung **neuer Technologien zur optimierten Nutzung der bestehenden Infrastruktur und zur Aufrechterhaltung der Netzstabilität** sowie deren Berücksichtigung im Planungsprozess

2. ***Netz- & Systembetrieb: Gewährleistung der Betriebssicherheit für die Systemtransformation***
    - Einrichtung eines standardisierten Systems für operative Planungsprozesse und -werkzeuge und **Einführung einer operativen Arbeitsumgebung** zur Unterstützung des Online-Systembetriebs
    - Anpassung des **Netzengpassmanagements und der Redispatch-Planung sowie der erforderlichen betrieblichen Prozesse**, um den zeitlichen Versatz zwischen der Entwicklung der erneuerbarer Energien und der Netzinfrastruktur zu schließen
    - Entwicklung und Implementierung einer **hochautomatisierten und effizienten Datenverwaltung**
    - Implementierung **erforderlicher Methoden zur Prognose der EE-Einspeisung** für die Unterstützung des Systembetriebs
    - Implementierung von **erweiterten Anwendungen zur Beobachtung und Steuerung von EE-Anlagen** mit dem Ziel, die Systemstabilität zu unterstützen und die Belastbarkeit des Systems zu erhöhen
    - Entwicklung von Prozessen und Instrumenten zur Überwachung der **Leistungsbilanz (‚Adequacy‘) und Erzeugungsflexibilität** gemäß den Anforderungen des ENTSO-e

3. ***Positionierung & Strategie: Entwicklung des ÜNB zum ‚Ermöglicher‘ der Energiewende***
    - Überprüfung der **Organisationsstruktur** im Hinblick auf die neuen Funktionen und Ressourcenanforderungen (Netzplanung, Systembetrieb, Energiemarkt, Digitalisierung, Regulierung)
    - **Stärkung der Strategieentwicklung**, um bestehende und zukünftige Herausforderungen und Trends zu antizipieren und klare strategische Ziele zu entwickeln, die mit den wichtigsten Interessensgruppen geteilt werden.
    - Entwicklung **angemessener KPIs zur Umsetzung der EU-Ziele gemäß CEP** und deren Berücksichtigung in den in Unternehmenszielen, -strategie sowie und konkreten strategische Maßnahmen
    - Intensivierung der **Öffentlichkeitsbeteiligung und des Bürger-Dialogs** als Schlüsselinstrument zur Verbesserung der Akzeptanz und letztlich der Beschleunigung der Infrastrukturentwicklung unter Einbeziehung der bedeutenden Interessensgruppen

4. ***Marktdesign & Flexibilität: Marktdesign zur Unterstützung der Systemtransformation***
    - Entwicklung **funktionierender Day-Ahead- und Intraday-Märkte** mit Rücksicht auf die gesetzlichen, vertraglichen und technischen Anforderungen.
    - **Preiskopplung** mit grenzüberschreitenden Energiemärkten als darauffolgender Schritt mit einem allmählichen Übergang von **einer expliziten zu einer impliziten Allokation von Übertragungskapazitäten**
    - Eine **Verbesserung der Liquidität** in den Energiemärkten sollte das Hauptziel für die Markteinführung in der Ukraine sein

- Potenzielle **Konfigurationen von Gebotszonen** für künftige EE-Ausbauszenarien in der Ukraine sollten analysiert werden, da sie die Netzentwicklung und die Marktergebnisse bestimmen werden. Als Schlüsselindikatoren sollten die erwarteten sozialen Wohlfahrtsgewinne gegenüber der Auswirkung auf die Liquidität betrachtet werden
- **Einhaltung der Leistungsbilanz und der Bedarf an Mechanismen zur Kapazitätserhaltung (Kapazitätsmärkte, -reserven)** sollten für die nächsten zwei Jahrzehnte im Einklang mit den künftigen EE-Zielen, dem Ausstieg aus der Kohle- und Kernkraft und der Entwicklung von Verbundnetzen analysiert werden
- **Die Gestaltung des Ausgleichsmarktes sollte überprüft werden,** um eine ausreichende Liquidität auf dem Ausgleichsmarkt zu gewährleisten, wobei die Schlüsselelemente die umfängliche Anwendung des BRP-Modells (einschließlich der EE-Stromerzeuger), die Durchführung strenger Kontrollen der BRPs, eine angemessene Preisgestaltung für Bilanzungleichgewichte und die Ermöglichung des Markteintritts kleiner flexibler Einheiten sein sollten
- Die effektive Präqualifizierung aller Erzeugungseinheiten für die Teilnahme am Ausgleichsmarkt stellt den ÜNB vor enorme Arbeitsbelastung, die eine positiven Entwicklung der Liquidität beeinträchtigen könnte. **Ukrenergo kann von der Entwicklung und dem Betrieb einer IT-Plattform für eine effiziente Präqualifizierung, Betrieb und Überwachung der Marktteilnehmer profitieren**

5. ***Regulierung & Finanzierung: Entwicklung des der Rahmenbedingungen zur Unterstützung der Systemtransformation***
   - Die Anwendung der Anreizregulierung in der Ukraine kann Anreize zu Effizienzverbesserungen für DSOs und TSOs setzen; **zusätzliche Elemente würden erforderliche werden, um den Ausbau der Netzinfrastruktur aufgrund der Zunahme Erneuerbare** zu finanzieren
   - **Angemessene technologiebezogene Ausgestaltung von EE-Auktionen sowie Stabilität bzw. des Designs über mehrere Auktionsrunden** werden empfohlen, damit sich der Markt der Anforderungen annehmen und sich entsprechend entwickeln kann
   - Das in Deutschland verwendete **Marktprämienmodell für Erneuerbare Energien** stellt eine Option für die Ukraine dar, da es sich als ein wirksames Instrument für die Marktintegration erneuerbarer Energien bewährt hat
   - Die **Einhaltung der EU-Vorschriften und -standards** wird einen engen Dialog und eine Ausarbeitung mit dem Ministerium und der Regulierungsbehörde erfordern, und insbesondere die Änderungen in der Gestaltung des Strommarktes aufgrund der CEP-Verordnung werden die höchsten Anforderungen an Ukrenergo stellen
   - **Netz- und Systemregeln (Grid Codes) sind ein wichtiges Instrument für Ukrenergo**, um eine kostenoptimale Integration der EE in das System zu erreichen
   - **Anpassungen bzw. Flexibiltät in den Netzzugangs- und -anschlussregeln** stellen eine Lösung für Ukrenergo dar, um die Nutzung der bestehenden Infrastruktur zu optimieren und die Integration von Erneuerbare Energien in Situationen nicht ausreichender Netzanschlusskapazität zu beschleunigen
   - **Locational signals could allow internalizing grid investment costs in the deployment of RES capacities to ensure alignment of the RES deployment with the grid development**. The renewable auctioning in Ukraine could take into account pre-selection of best localizations with regards to the grid potential. Alternatively, the incorporation of locational components in the RES support schemes could be considered
   - **Standortsignale könnten eine Netzinvestition in bei der Bereitstellung von EE-Kapazitäten berücksichtigen, um die zeitliche Entwicklung der Erneuerbaren Energien an die Netzentwicklung anzupassen.** Bei der Durchführung von Ausschreibungen für EE-Anlagen könnte eine Vorauswahl der besten Standorte im Hinblick auf das Netzpotenzial berücksichtigt werden. Alternativ könnte die Einbeziehung lokaler Standortfaktoren für den Fördermechanismus in Betracht gezogen werden.
   - **Ukrenergo sollte gesetzlich in der Lage sein, Einspeisung aus EE-Anlagen aus Gründen der Systemsicherheit als nachrangige Maßnahme** in einem transparenten Verfahren zu verringern. Dies sollte mit einer angemessenen finanziellen Entschädigung des Erzeugers und des Bilanzkreisverantwortlichen erfolgen.

Die dargelegten Gaps der fünf Themenschwerpunkten bilden die Grundlage für eine gründliche Identifizierung der Aufgaben zur Gestaltung der Energiewende. Zusammengefasst bilden sie für Ukrenergo den Ausgangspunkt für die Erstellung eines zukünftigen Fahrplans für die Transformation des Energiesystems der Ukraine.

2 Executive Summary

The Ukrainian power system transformation and RES challenges

Renewable Energy Resources (RES) constitute a major opportunity for Ukraine: the country possesses high RES potential and abundance of areas suitable for the deployment of RES power plants. Further, Ukraine lies in the direct vicinity of the European Union, allowing it to become an exporter of excess RES electricity. The recently released "*Vision for energy transition for Ukraine"* shows that this opportunity is identified by the Ukrainian government, by setting a target of RES shares increasing to 70% by 2050, combined with a coal phase-out, a reduction of nuclear generation to 20-25% and a market integration with the European Union. This ambitious trajectory started already in 2017, when Ukraine adopted new energy strategy and signed the Agreement on the Conditions for the Future Interconnection of the Power System of Ukraine with the Power System of Continental Europe. Ukraine aims to increase the energy produced from renewable sources and hydropower plants to 11% by 2025 and 25% by 2035. By committing to the European Union targets, Ukraine will need to reduce the CO2 emission (40% by 2030), to increase the share of renewable energy (min. 32% by 2030), and to enhance the European energy trading across the borders (70% minimal remaining available margin capacity on the interconnectors) as stated in the European Union Clean Energy Package (CEP). Those targets require a radical transformation of the Ukrainian power system.

Today, the energy generation mix is dominated by fossil fuels: nuclear energy supplies more than 50% of generated power, followed by coal exceeding 30%. Natural gas is mainly used in Combined Heat and Power (CHP) plants for district heating purposes. The total generation capacity in Ukraine reaches 49,7 GW, with highest share being coal (60%) and nuclear power plants (25%). These large-scale generation facilities are built closed to the demand centres in North and in West Ukraine. Hydropower is the most significant renewable energy contributor amounting for 6-7% of generated electricity. Other types of RES contribute about 2% of the generated energy at the moment. An increase of wind and solar RES generation capacity to 4500 MW by 2025 was foreseen in the energy strategy of 2017. Remarkably, this target has been already reached by the end of 2019 and the connection requests reach even 11000 MW. Those figures indicate clearly the rapid and uncertain development of RES capacity.

Planning the optimal development of the future power system under this uncertainty is a major challenge for Ukrenergo. Rising RES shares bring the need for a radical transformation power system:

1. **Grid development:** Due to the higher RES potential, a large share of RES will be deployed to the Southern area of the country, and the generated energy will need to be transported to the Northern and Western areas. **These new power flow patterns will lead to increasing grid congestions** that should be solved by grid extensions.

2. **System Balancing:** RES will increase the variability in the system (higher ramping rates) and the operational uncertainty (forecast errors). Due to the high share of inflexible conventional generation, **the system will experience an increasing need for new flexibility resources for balancing the system**. New system balancing approaches should be deployed in order to ensure operational security.

3. **Distributed generation:** Small- to medium scale RES generators will be connected to all system voltage levels including distribution networks. This will radically affect the system architecture and Ukrenergo will have to cope with bidirectional and highly volatile power flows. **The future system operation calls for new data management and control systems** in order to steer the large number of dispersed generators situated in the lower voltage levels.

4. **System stability:** With increasing the shares of inverter-connected RES units, power systems need to cope with **challenges related to increased non-synchronous power injections**. Related problems are the lack of rotational inertia and increased rate of change of frequency in the system, as well as issues with voltage provision, lower short-circuit levels and angular stability. New grid tech-

nologies (e.g. HVDC, FACTS) should be adopted that will support the stability of the system, especially until it achieves a sufficiently strong synchronous interconnection to the interconnected European system.

This system transformation will affect practically all domains of responsibility of Ukrenergo, with key components the rapid grid expansion, interconnection with the ENTSO-e system, and the establishment of a well-functioning ancillary service market. Analysing these challenges has been the focus of the system transformation project.

Key system transformation gaps for an optimised integration of renewable energies in Ukraine

Five expert workshops have been organised as depicted in Figure 2, covering the five main building blocks. By using the key lessons learnt from 20 years of RES integration in Germany as starting points, the discussion of the lessons learnt and the current situation in Ukraine during the workshops enabled the identification of the respective implementation gaps.

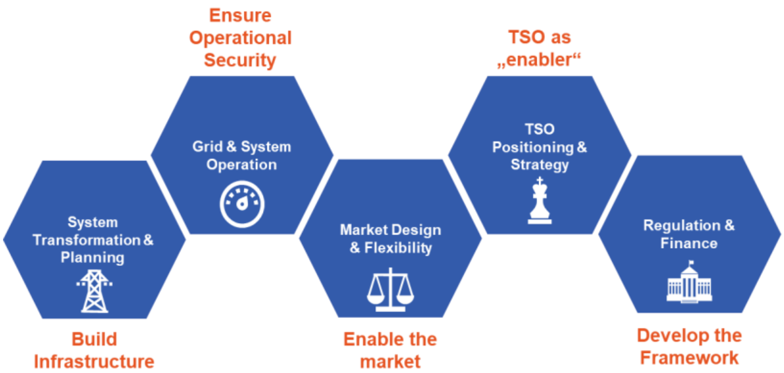

Figure 2 – Overview of the five thematic areas of the workshops

The bottom-up gap identification was further synthesized to the present gap analysis report, identifying the opportunities and optimization potential for Ukrenergo, and lately the challenges to integrate RES in Ukraine in a sustainable and secure way. The key gaps from the TSO perspective are mapped according to the five building blocks:

1. ***System Transformation and Planning: managing the RES-driven infrastructure development***:
   - Adoption of **scenario planning methodologies** tailored to the specificities of Ukraine for optimal robust decision making under the high uncertainty characterising the current environment.
   - Evolution of the decision support processes regarding infrastructure development including **data, tools and processes** for optimal grid planning
   - **Harmonisation of Ukrainian grid codes** with the ENTSO-e
   - Development of a **long-term strategy for the deployment of interconnectors** to Europe for cross-border trading and reserve sharing
   - Active role of **new technologies to optimize use of existing infrastructure and maintain grid stability** to be considered in the planning process

2. ***Grid & System Operation: ensuring operational security for the system transformation***
   - Establishment of standardised system for operational planning processes and tools and **introduction of an operational planning layer** to support online system operation
   - Implementation of **congestion management and redispatch** planning and operational processes in order to manage the gap between RES deployment and grid development
   - Develop and implement a highly **automated and efficient data management solutions**
   - Implement enhanced methods for **RES generation forecasting** for system operation support
   - Implement advanced **RES controllability and observability** means with the aim to support system stability and increase system resilience

- Develop processes and tools to monitor **generation and flexibility adequacy** according to the ENTSO-e requirements

3. ***TSO positioning and strategy: transforming the TSO to the enabler of the energy transition***
    - Review the **organisational structure** with regards to the new functions and capacity requirements (grid planning, system operation, energy market, digitalisation, regulation)
    - Reinforce the **strategy development department** to anticipate emerging issues and future trends in the TSO ecosystem and develop clear strategic goals shared with key stakeholders
    - Develop adequate **KPIs to translate EU CEP targets** into company's objectives, strategies and concrete strategic actions
    - Enforce **public participation and dialogue** as key tool for improving the speed of infrastructure development, involving all key stakeholders

4. ***Market Design & Flexibility: market design to support the system transformation***
    - Establishment of a **proper functioning of the day-ahead and intraday markets** with regards to the legal, contractual and technical requirements.
    - **Price coupling** with cross-border energy markets as a next step with a gradual transition from **explicit to implicit capacity allocation**.
    - Improving **market liquidity** should be the key target for the market introduction in Ukraine.
    - Potential **bidding zone configurations** for future RES expansion scenarios in Ukraine should be analysed, as they will define the grid development and market outcomes. Key factors to consider should be the expected social welfare gains against liquidity impacts.
    - **Generation adequacy** and need for **Capacity Remuneration Mechanisms** should be analysed for the next two decades in line with the future RES projections, coal and nuclear phase out and interconnection development.
    - **The balancing market design should be reviewed** to ensure sufficient liquidity in the balancing market, with key elements the application of strict BRP control, universal application of BRP model (including RES generators), proper pricing of imbalances, enabling the market entrance of small flexible units.
    - The effective prequalification of all the units to participate in the balancing market is a massive work that could place a hurdle to the development of liquidity. **Ukrenergo could benefit from developing and operating a balancing platform for the efficient prequalification, operation and monitoring of the market.**

5. ***Regulation and Finance: Develop the framework to support the system transformation***
    - The application of incentive regulation in Ukraine could stimulate efficiency improvements for DSOs and TSOs but would need **additional elements to facilitate RES-related grid investments** to manage the energy transition
    - Well-designed **technology-specific auctions with stable design** are recommended so that the market can adapt and improve.
    - The **Feed-in-Premium (FiP)** model used in Germany could be an option for Ukraine as it is an effective tool for market integration of renewables
    - The **compliance with EU rules and standards** will require a close dialogue and elaboration with the ministry and regulator, and in particular the changes in the electricity market design due to CEP regulation will set the highest requirements for Ukrenergo
    - **Grid Code are a critical tool for Ukrenergo** to achieve cost-optimal integration of RES in the system
    - **RES Flexible access regulation** represents one solution for Ukrenergo to optimise the use of existing infrastructure and to accelerate RES integration in lack of sufficient full grid connection capacity
    - **Locational signals could allow internalizing grid investment costs in the deployment of RES capacities to ensure alignment of the RES deployment with the grid development**. The renewable auctioning in Ukraine could take into account pre-selection of best localizations with regards to the grid potential. Alternatively, the incorporation of locational components in the RES support schemes could be considered.

- **Ukrenergo should be able to curtail RES units for system security reasons as a last resort measure** under a transparent process, with a proper financial compensation of the producer and the BRP for the avoided production.

The presented gaps of the five building blocks form the basis for a thorough identification of the tasks for shaping the energy transition. Concluded, they form the starting point for the development of a future roadmap for Ukrenergo for the system transformation for an optimised integration of renewable energies in Ukraine.

3 Introduction

3.1 Ukrainian Power System & Integration of Renewables

Renewable Energy Resources (RES) constitute a major opportunity for Ukraine: the country possesses high RES potential and abundance of areas suitable for the deployment of RES power plants. At the same time, it lies in the direct vicinity of Europe, allowing it to become an exporter of excess RES electricity. The recently released "*Vision for energy transition for Ukraine"* shows that this opportunity is identified by the Ukrainian government, by setting a target of RES shares increasing to 70% by 2050, coal phase-out, reduction of nuclear generation to 20-25% and market integration with Europe. This ambitious trajectory started already in 2017, when Ukraine adopted new energy strategy and signed the Agreement on the Conditions for the Future Interconnection of the Power System of Ukraine with the Power System of Continental Europe. Ukraine aims to increase the energy produced from renewable sources and hydropower plants to 11% by 2025 and 25% by 2035. By committing to the European targets, Ukraine will need to reduce the CO2 emission (40% by 2030), to increase the share of renewable energy (min. 32% by 2030), and to enhance the European energy trading across the borders (70% minimal remaining available margin capacity on the interconnectors) as stated in the European Union Clean Energy Package (CEP). Those targets require a radical transformation of the Ukrainian power system.

Today, the energy generation mix is dominated by fossil fuels: nuclear energy supplies more than 50% of generated power, followed by coal exceeding 30%. Natural gas is mainly used in Combined Heat and Power (CHP) plants for district heating purposes. The total generation capacity in Ukraine reaches 49,7 GW, with highest share being coal (60%) and nuclear power plants (25%). These large-scale generation facilities are built closed to the demand centres in North and in West Ukraine. Hydropower is the most significant renewable energy contributor amounting for 6-7% of generated electricity (Ukrinform, 2018b). Other types of RES contribute about 2% of the generated energy at the moment. An increase of wind and solar RES generation capacity to 4500 MW by 2025 was foreseen in the energy strategy of 2017. Remarkably, this target has been already reached by the end of 2019 and the connection requests reach even 11000 MW. Those figures indicate clearly the rapid and uncertain development of RES capacity.

Planning the optimal development of the future power system under this uncertainty is a major challenge for Ukrenergo. Rising RES shares bring the need for a radical transformation power system:

1. **Grid development:** Due to the higher RES potential, a large share of RES will be deployed to the Southern area of the country, and the generated energy will need to be transported to the Northern and Western areas. **These new power flow patterns will lead to increasing grid congestions** that should be solved by grid extensions.
2. **System Balancing:** RES will increase the variability in the system (higher ramping rates) and the operational uncertainty (forecast errors). Due to the high share of inflexible nuclear generation, **the system will experience an increasing need for new flexibility resources for balancing the system**. New system balancing approaches should be deployed in order to ensure operational security.
3. **Distributed generation:** Small- to medium scale RES generators will be connected to all system voltage levels including distribution networks. This will radically affect the system architecture and Ukrenergo will have to cope with bidirectional and highly volatile power flows. **The future system operation calls for new data management and control systems** in order to steer the large number of dispersed generators situated in the lower voltage levels.
4. **System stability:** With increasing the shares of inverter-connected RES units, power systems need to cope with **challenges related to increased non-synchronous power injections**. Related problems are the lack of rotational inertia and increased rate of change of frequency in the system, as

well as issues with voltage provision, lower short-circuit levels and angular stability. New grid technologies (e.g. HVDC, FACTS) should be adopted that will support the stability of the system, especially until it achieves a sufficiently strong synchronous interconnection to the interconnected European system.

This system transformation will affect practically all domains of responsibility of Ukrenergo, with key components the rapid grid expansion, interconnection with the ENTSO-e system, and the establishment of a well-functioning ancillary service market. Analysing these challenges has been the focus of the system transformation project.

3.2 System Transformation Project

The aim of the consultancy project "System transformation for an optimised integration of renewable energies in Ukraine" is to **support the transmission system operator Ukrenergo in the system transformation to an energy system with a high share of renewable energies.** A cost-efficient and reliable integration of renewable energies requires a substantial transformation of the energy sector, which includes technical, legal and regulatory fields of action. In view of the complexity of the task, a multi-layered approach involving all stakeholders is required.

Work package 1 has analysed the current situation in Ukraine related the integration of renewables. Building on this knowledge, Elia Grid International (EGI) has conducted bilateral exchanges with Ukrenergo to clarify important key challenges and thematic areas to be covered in the project, documented in the As-Is Assessment Report describing the RES integration preparedness of Ukraine. Five 2-day workshops covering the topics **System Transformation & Planning, Grid & System Operation, Transmission System Operator (TSO) Positioning & Strategy, and Regulation & Finance Reform** (Figure 3) have been conducted in the period September to December 2019 in the headquarter of 50Hertz in Berlin. The key element in the workshop concept is the exchange of key lessons learnt in Germany and the assessment of the current strengths and weaknesses of the Ukrainian power system with respect to the RES integration. The lessons learnt of each presentation (work session) have been discussed and prioritized in order to map the strengths, weaknesses and challenges of Ukrenergo. All feedback of the workshop participants has been detailed in five Workshop Reports.

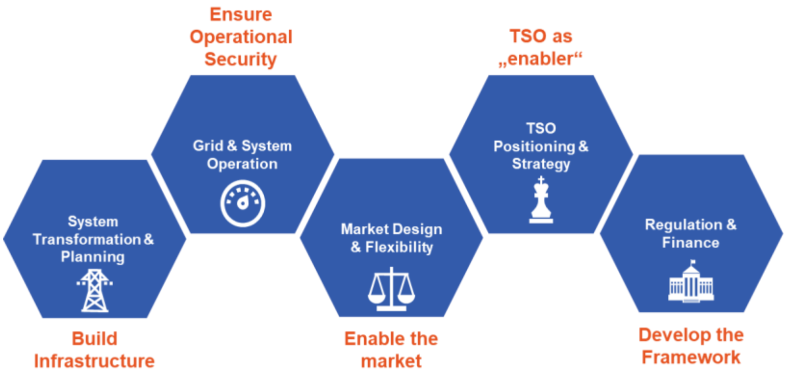

Figure 3 – Overview of the five thematic areas of the workshops

The present **Gap Analysis Report (Work package 2)** presents a comprehensive synthesis of the workshop findings. The focus is to map the strengths and weaknesses of the Ukrainian power system as well as the assessment of the need for optimisation and the existing optimisation potential with regards to the capability to integrate a high share of RES. The gaps analysis is presented in five key areas according to the workshop structure:

- **System Transformation & Planning (Section 4):** the needed infrastructure development
- **Grid & System Operation (Section 5):** the needed adaptations to ensure operational security

- **TSO Positioning & Strategy (Section 6):** making the TSO the system transformation “enabler”
- **Market Design & Flexibility (Section 7):** market design to support the energy transition
- **Regulation & Finance (Section 8):** framework requirements for the transformation process

4 System Transformation & Planning

The international practice shows that in systems with low load growth and rapid RES development such as in Ukraine, the system development is mainly driven by the deployment of RES generation instead of the load growth. In the system planning practice, a **paradigm shift towards RES-driven grid development** needs to be recognised and internalised by Ukrenergo. In the Figure below, an overview of the main drivers of this paradigm shift are summarised, based on the experiences from the German power system.

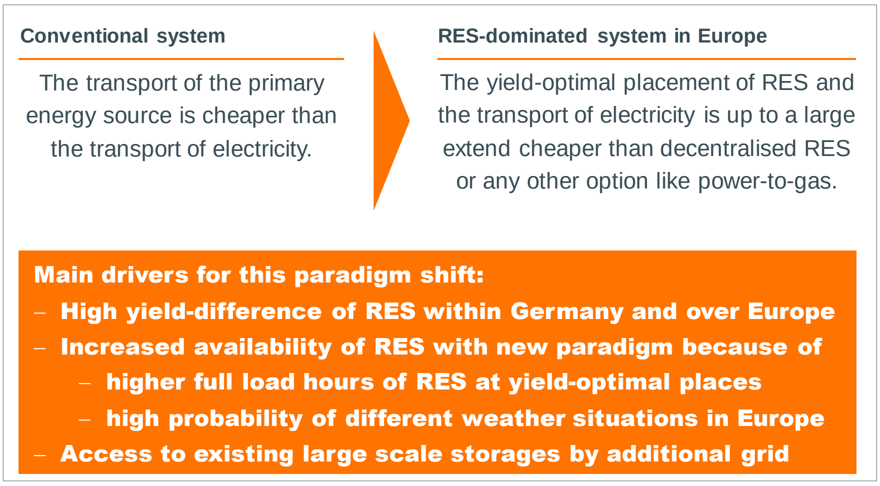

Figure 4: Paradigm shift in the system transformation

RES-driven grid development brings significant challenges and calls for a radical change in the system planning processes. RES development is more decentralised, and its scale and speed of deployment are more difficult to be predicted than large-scale centralised conventional generation. Further, the integration of high share of RES into the system will create changes in the power flow patterns, either due to the location of RES generators far from load centres or due to their connection at lower voltage levels (distribution grids). Consequently, the existing grid development practices that have been established for centralized conventional generation system should be transformed towards a RES-focused grid planning. In this chapter, the key gaps identified in the traditional way of system planning will be discussed and recommendations are given for the transition towards modern grid planning practice for systems dominated by renewables.

Grid Development: incorporation of uncertainty for supporting optimal robust decisions

Ukrenergo's system planning has to **anticipate the development of RES and synchronise the grid expansion with the RES development** in order to maintain effectively the RES uptake. The current system planning processes in Ukrenergo evolve in order to identify the optimal grid investment decisions. However, due to the increased uncertainty regarding the future RES deployment, there are risks of not reaching optimal decisions, which would either lead to sustained congestions in case the projects are not properly prioritised, or to stranded assets in case of radical changes in the expected RES deployment. The Ukrenergo system planning practice should base decision making processes on **robustness analysis**, taking into account the whole spectrum of uncertainty regarding the future RES developments and all related policy framework. For a robust decision-making it is recommended that Ukrenergo applies **scenario planning methodologies** in the system planning. In the figure below, the application of such an analysis to the case of 50Hertz is presented, where five scenarios were developed with a horizon on 2035, capturing the uncertainty of reaching or not policy objectives (regarding RES targets) as well as the differences in the implementation, i.e. prosumer-oriented distributed paradigm vs large-scale RES deployment. The grid development needs for all divergent scenarios were analysed, and the grid investments were classified as a) investments that are needed across all scenarios which should be prioritised (robust decisions) and b) investments conditional to scenarios (i.e. reinforcements needed to support the large-scale offshore deployment).

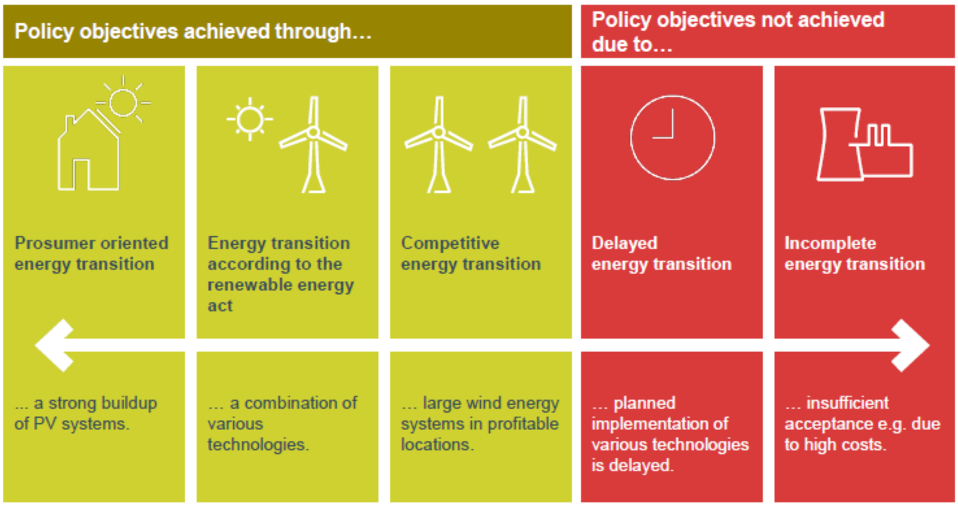

Figure 5: Five Scenario Storylines as developed for the 50Hertz Energiewende Outlook 2035 study

Besides, the system transformation towards a RES-focused ecosystem does not remain in the national context but it requires **regional solutions**. As a future ENTSO-e member, Ukrenergo will be interconnected with the ENTSO-e system. Thus, it will need to **harmonise the existing Ukrainian grid codes with the ENTSO-e grid codes**[1]. Furthermore, Ukrenergo's system planning should **consider an increased usage of interconnectors for cross-border trading and reserve sharing in the strategic grid development planning**. The cross-border power exchanges with Europe could increase the impact from external power systems on the Ukrainian Integrated Power System (IPS) leading to possible changes in power flow patterns in the grid. The European experience shows that flow patterns are radically affected by international trade of energy. Keeping in mind the significant RES potential and vicinity of Ukraine to Europe, a large-scale RES deployment could create the conditions for the country to develop into a net exporter of excess RES electricity.

Currently, the analysis of the Ukrainian system is performed considering more "isolated" scenarios regarding exchanges with Europe. It is recommended that scenarios with higher interconnection to Europe are analysed in combination with the RES deployment in the country. Those additional scenarios enable an integrated assessment of the benefits and alignment of the interconnection with RES deployment targets. In this respect, the development of a **long-term strategy for the deployment of interconnectors to Europe** is recommended. As part of this strategy, the role of power flow controlling elements and technologies allowing asynchronous coupling to Europe as short-term bridging solutions should be considered, such as Phase-Shifting Transformers (PST), High Voltage Direct Current (HVDC) corridors or Back-to-Back (B2B) converter stations.

Data, Tools and Processes: need for evolution of the decision support processes

[1] The harmonisation process is an ongoing process in Ukrenergo as part of the preparation of the synchronisation of Ukraine's power system with the grid of Continental Europe

Following the paradigm shift, significant impacts of RES on the system planning practice have been identified. First, the amount and the diversity of the data used for system planning increase. The quality of the data will be crucial for the accuracy of the system development plan. Second, the high penetration of volatile RES requires the application of probabilistic methodologies in grid planning to capture the variability and uncertainties of RES. Third, grid expansion projects should be planned in a synchronised way with the RES deployment to avoid stranded investments in the grid infrastructure and to maximise the RES uptake. Last but not least, the system stability should be re-analysed and maintained in accordance with the development towards a system mainly consisted of converter-based RES.

The answer to the described impacts is **the establishment of an advanced toolchain and data management in system planning and development.** Ukrenergo's experts have recognised the toolchain and data management as the most important elements to be realised in the transformation of Ukrenergo's system planning practice. Practical experiences from 50Hertz show that data management and tool functionalities need to be radically enhanced to allow proper analysis of RES impacts. New data formats and solutions for data management will need to be applied to efficiently conduct studies on an hourly resolution for all planning years, in contrast to current methods that focus on the analysis of single operational snapshots. Input data need to be available in high quality and proper data management and automations are required to handle the large amount of data efficiently. The process of data collection and - preparation should start early to provide the input to the toolchain when needed. The realisation of a holistic data management solution coupled with the toolchains demands the availability of top Information Technology (IT) and Data Science experts in Ukrenergo.

A high benefit of the toolchain is the **high level of automation and standardisation**. The tool chain will include **series of standardized tools** for scenario development, market modelling, grid calculation, stability analysis and data visualisation. The **standardised and aligned interfaces** between the tools will ensure a **smooth data flow** between the tools. As a result, the highly automated system planning process will enable Ukrenergo to produce simulation results for the 8760 hours of the year and identify grid expansion measures in proper time and quality.

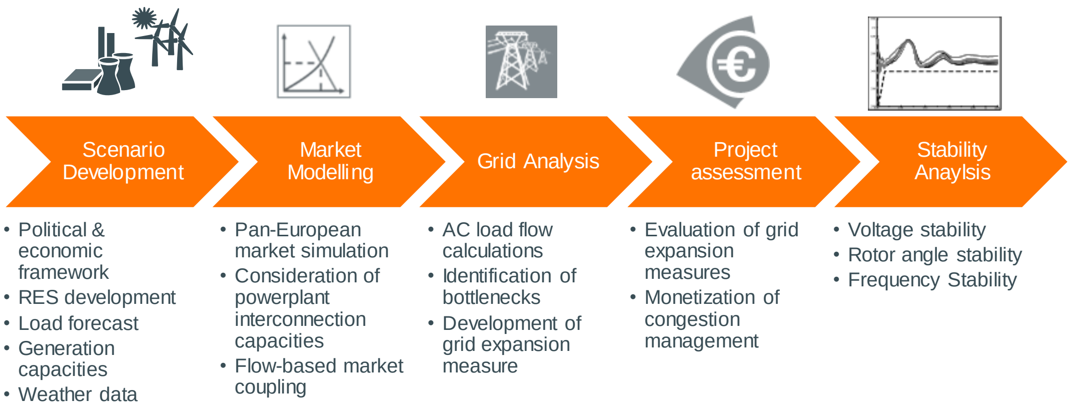

Figure 6: System planning toolchain overview based on 50Hertz

Role of new technologies to enable optimal use of grid infrastructure

As aforementioned, the system is undergoing a paradigm shift resulting in a decrease of conventional generation and an increase of converter-based decentralised RES generation, causing a need for long-distance electricity transport and interconnection between the European countries.

Power flow patterns may change due to the variability and location of RES, while the increasing share of converter-based generation requires a change of the current voltage provision. Ukrenergo is recommended to study the implementation of new transmission technologies that can be used to control power flows and provide system services (e.g. voltage support). A set of possible needs and solutions are listed below:

- **Increasing need for large-scale long-distance electricity transportation**: potential solution for long-distance transportation is the application of **HVDC overlay corridors** (see figure below). This solution was adopted in Germany in order to allow the transportation of excess RES production from the north of the country to the load centres in the south. Similar conditions may apply in Ukraine in the case excess RES production in the south should be transported towards the north and west regions.

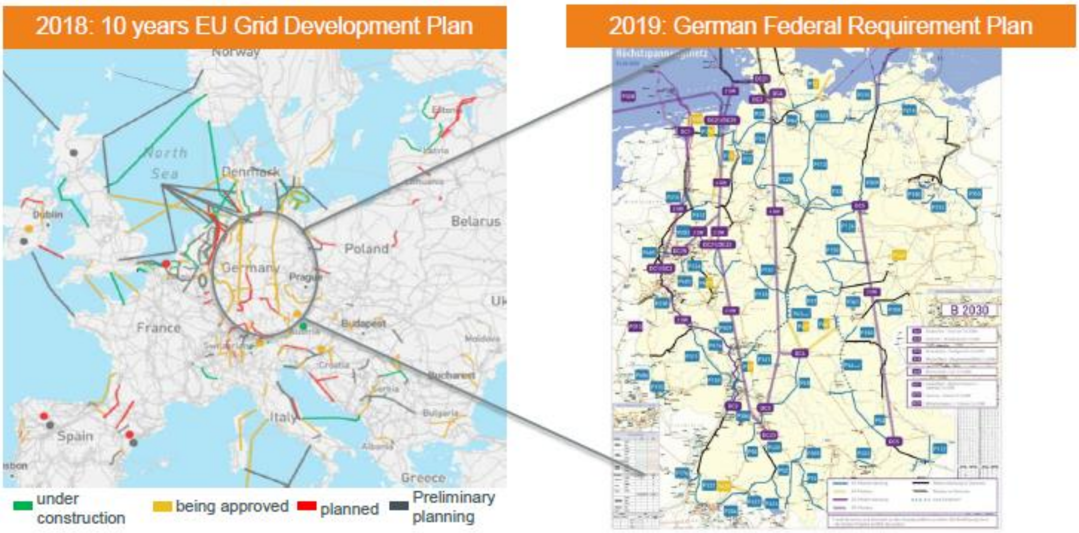

Figure 7: Overview of the HVDC north-south corridors in Germany

- **Decreasing reactive power compensation from large-scale conventional power plants:** with higher shares of RES, the system should be prepared to operate under situations of reduced amount of conventional units and high presence of converter-based generation units. Installation of **Flexible Alternate Current Transmission Systems (FACTS) devices** such as static synchronous compensator (STATCOM) should be considered to ensure the system stability and preventing voltage collapse.
- **Increasing loading of grid elements in particular lines and transformers in the periods of high wind and solar production**: grid-usage optimization technologies such as **Superconductors or Dynamic Line Rating**, or grid congestion management **concepts** such as **grid booster** should be considered;
- **Asynchronous interconnection of Ukraine with the ENTSO-e network**: to bridge the period until a full synchronous interconnection of Ukraine IPS to the ENTSO-e system is in place, **HVDC Back-to-Back solutions** could be considered. A similar concept has been deployed for the connection of Germany and Denmark, as shown in the figure below (Project Kriegers Flak).

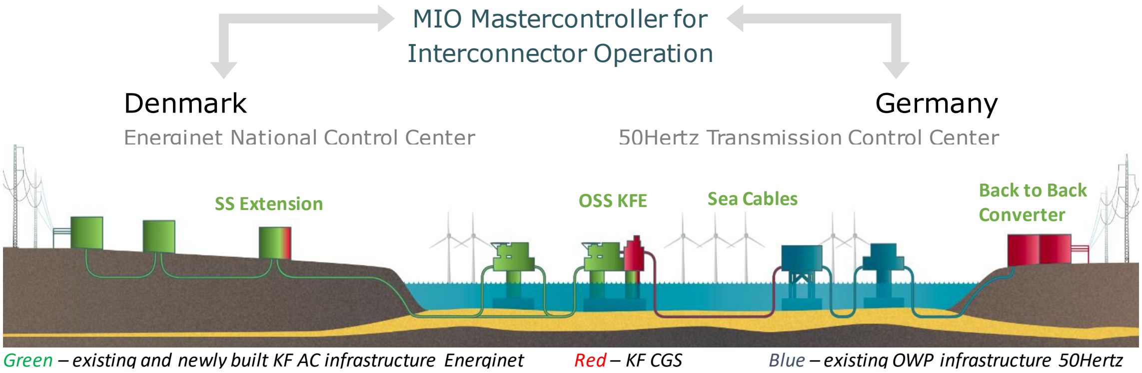

Figure 8: Example Project Kriegers Flak Combined Grid Solution with HVDC B2B

It is of high relevance that **Ukrenergo starts to develop an in-house expertise in those new technologies and future grid operation concepts**. These technologies will be enablers for a cost-efficient, reliable and secure integration of RES.

5 Grid & System Operation

Traditionally, the grid and system operation has been based on relatively stable conditions: The TSO receives from the large generators a precise dispatch schedule early in advance that is used to predict the loading situation on the grid at relatively high accuracy. Based on that information, the TSO can define a concrete list of grid and system operation commands in advance.

A RES-focused system will create new requirements for the grid and system operation practice due to the high intermittent production and its impact on the volatile loading of the grid. In order to actively operate the system under the new conditions, the TSO will require improvements in the operational planning processes with regards to processing operational information, precise modelling of the grid infrastructure, and providing valuable recommendations to the system operator.

Since Ukrenergo's system operational practice has been designed for a system dominated by large-scale conventional generation, the integration of RES will increase the need to implement several changes in the organisation and in the practice in order to cope with the new operational challenges. They are described in the following section as the gaps in Grid- and System Operation to prepare Ukrenergo for the transformation.

Establishment of standardised system for operational planning processes and tools

High penetration of renewables requires a shift in the system operation practice. System operational planning is becoming important because of the high level of uncertainty in the system. This uncertainty needs to be predicted accurately and controlled properly in the system operation in order to maintain the high level of system security. Furthermore, the interconnection with ENTSO-e and market coupling requires Ukrenergo to implement new tools and processes, e.g. Flow-based market coupling (FBMC) capacity calculation, in the future in order to know the impact of cross-border trading on the system.

Ukrenergo is recommended to **review the existing system operation and implement new RES-driven and ENTSO-e conforming processes, standardised tools and standardised interfaces between the tools**. Additionally, Ukrenergo is required to establish **standardised interfaces** with systems from external stakeholders such as **market participants**, **neighbouring TSOs**, distribution system operators (**DSO)**, relevant **generation and consumption units**, etc. to exchange efficiently information for the system operation. The processes shall be highly automated to save the lead-time.

As a concrete practice example, the high penetration of RES will impede the coordination between the long-term grid expansion projects and the short-term system operation measures such as planned outages for maintenance because of the uncertain load flow situations. The solution for a better coordination is the implementation of **mid-term planning** process as a bridge among the long-term and short-term activities. As a result, Ukrenergo can optimally allocate resources between projects and close gaps between the grid operation activities.

Another practical case of an important tool to be implemented in the system operational planning is the **calculation of the grid reserve capacity from the power plants** that the TSO would need for **congestion management** purposes. Until now, the determination of the grid reserve is not done via a calculation tool which leads to inefficiency in terms of grid reserve size and locations.

Moreover, Ukrenergo is recommended to **continuously improve** the processes and tools in the system operation. The goal is to maximise the level of process automation. **Process automation** will immediately help Ukrenergo to reduce the level of manual work, optimize time and resources, as well as increase the quality of results. Process automation becomes indispensable at high shares of RES due to the integration of real-time data (10-40% RES) and enhanced real-time cooperation between TSOs and DSOs (>40% RES)

As standard practice in conventional-generation dominated systems, current system operation practices in Ukrenergo focus more on the online operation of the system. **An operational planning layer should be developed to perform all needed processes and analyses needed in order to support the online operation of the system.** This operational layer is currently missing and should evolve with the increasing RES deployment, in line with the challenges identified by the online operators.

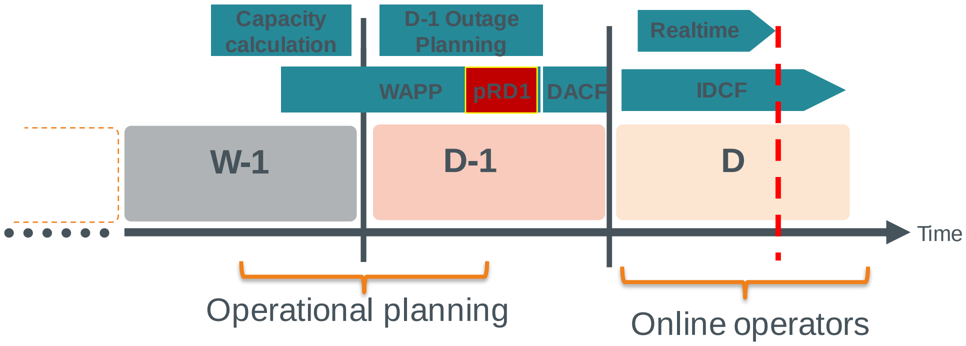

Figure 9: Timeframes of congestion management processes

Congestion Management and redispatch

The increase of renewable energies in Ukraine will change the location of generation and therefore an increase in the loading of transmission system is expected. To solve congestions and operate the system within its technical limits, an important measure is the so-called generation redispatch, a geographical re-allocation of locational infeed, as well as RES curtailment. **Congestion management will become an important task of Ukrenergo for managing security of supply.**

The dimensioning of the Redispatch Capacity is an iterative process from week-ahead to close to real time. Starting week-ahead enables to identify higher potential for redispatch compared to the day-ahead and intraday timeframe. **Ukrenergo should prepare the redispatch dimensioning as a rolling process for different time horizons.** It is important to the timely identification as the redispatch potential reduces with time, for example as some generation units are restricted by the activation time or will sell their capacity on the energy market. **These processes would be needed to be established at Ukrenergo together with all its requirements related to staff needs, coordination, data, tools, settlement etc.**

In Germany, grid extension, interconnectors and power flow controllers such as PSTs are measures to address costly redispatch and RES curtailment, and in the 50Hertz control area, RES curtailment has been stabilized and redispatch costs were significantly reduced in despite of an RES expansion of 2,400 MW (2018). Grid extension has proven to be the most effective solution to reduce the costs of generation redispatch and RES curtailment. **Early identification of future congestions is necessary in order to reduce risk exposure to redispatch costs.**

Current feed-in management legally separates between redispatch of conventional generation and curtailment of RES. However, the participation of RES will become indispensable for operational management in a system that is increasingly characterized by renewables. **Hence, the participation of renewables for grid congestion alleviation will become necessary for the secure operation of the Ukrainian power system.**

Trade flows and physical flows continue to deviate more strongly from each other due to the higher level of interconnection; therefore, coordinated congestion management between neighbouring countries becomes more important. While redispatch and phase shifters provide a short-term remedy, European grid expansion is the most efficient solution in the long-term. Redispatch is a costly measure to sustain security of supply and should be replaced by new grid capacity or technologies for power flow control (e.g.

phase shifting transformers). As the physical flows differ from the economical transaction, energy trade affects the loading of neighbouring transmission grids. **As a result, with higher interconnection level of Ukraine, efficient and secure solutions would require a grid development on regional level.**

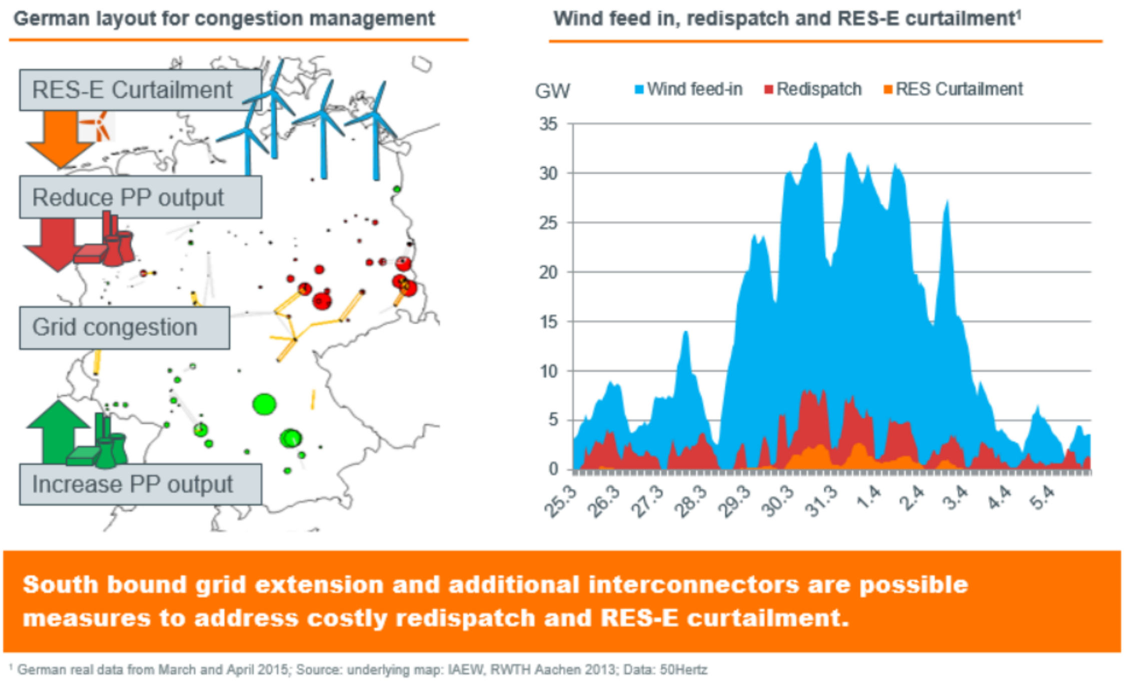

Figure 10: Need of congestion management in German transmission system

Strengthening the system operational data management

Future system operational practice will need to manage increasing amount of produced and collected data due to the decentralisation and the digitalisation of the system. Data will come from smart meters, sensors like dynamic line rating (DLR) sensors, RES forecasts, market information, outage plans, etc. In addition, the diversity and the velocity of changes in the data are increasing. For example, the installation of new technologies such as HVDC, FACTS, and energy storages will produce new type of data. Key **challenge for Ukrenergo is how to manage use the big amount of data effectively in the system operational planning.**

First, Ukrenergo needs to make sure that the **required data are available in the right time and the right format**. Until now, the data availability, in particularly from external stakeholders like market participants, is limited. Ukrenergo is recommended to work closely with the regulator and other stakeholders to define a standard for the input data and to secure the data availability in the regulation. Moreover, the clear roles and responsibilities, clear standards are crucial in the data provision and data transfer processes. The regulation needs to be well defined so that Ukrenergo can receive the data needed for the system operational planning in the right time, the right format and the right quality from all stakeholders.

Second, Ukrenergo is recommended to **develop and implement automated and efficient data management solutions.** As can be seen in the example of Day-Ahead Congestion Forecast (DACF) process for Germany presented in the figure above, the preparation of the 24 DACF files that are uploaded daily to the platform of the regional system security coordinator TSCNET is a highly automated process that combines inputs from different sources (power plant schedules and outage plans, RES infeed forecasts, control area exchanges). Such solutions able to quickly and automatically handle and analyse the big amount of data are necessary to provide the system operation with the right information at the right time in the right format in the decision-making.

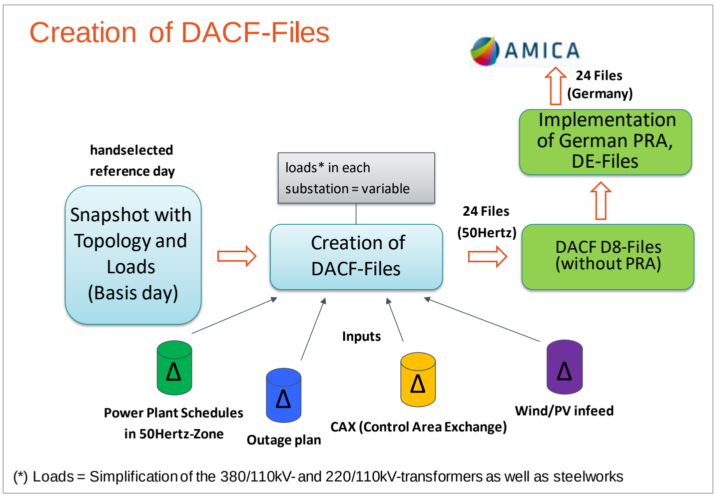

Figure 11: Data process for the day-ahead congestion management forecast

RES Forecasting: managing the operational uncertainty from RES

RES forecasting is becoming an essential element of system operational planning in a system with high RES shares, in order to manage the increasing impacts of RES in the system operation.

Ukrenergo is recommended to **develop a RES forecasting solution tailored to its needs**. Until now, Ukrenergo's primary need for RES forecasting focuses on the commercial use to forecast the renewable energy amount to be sold at the market. Since, there is no forecast provider at the market, Ukrenergo has developed an in-house forecast tool using the weather forecast information.

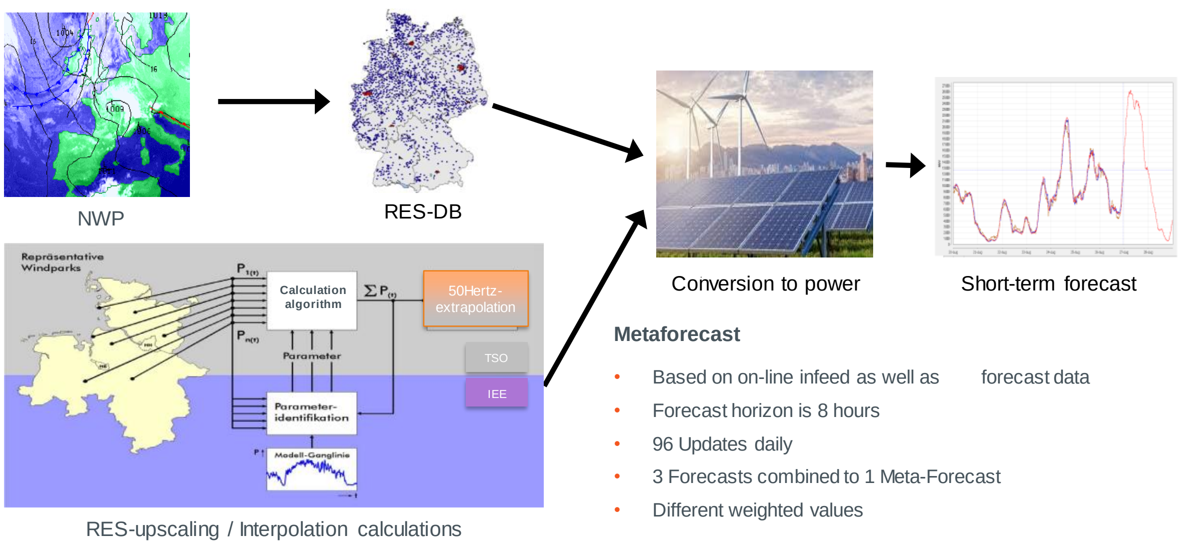

Figure 12: Meta-Calculation Model of 50Hertz short-term RES production forecasting

However, RES forecasting is not considered as a core business at a TSO. Ukrenergo is recommended to rather use outsourcing of forecasting services from different providers and to develop an own forecasting system **combining the forecasts in one meta-calculation model** (see figure below on how this process is applied at 50Hertz). A high growth of RES power generation will open a new market for forecasting providers and Ukrenergo could select and evaluate the best forecast providers for its forecasting solution. However, it is important to distinguish and keep separate the RES forecast needed for its operational needs of the TSO to the forecasts that market RES should perform in order to optimise their market commitments. A proper incorporation of balancing responsibility to RES will probably create needs for market players to forecast their production in order to optimise their portfolio. Such processes should be kept separate from the TSO RES forecasts that should aim on assessing the aggregate RES infeeds in the system.

Again, data is the core success element. For RES forecasting, the real production output is a crucial information which is needed for the forecast verification and continuously improvement of the forecasting model. However, Ukrenergo has limited access to the real production output data before curtailment at the RES generation sites. Thus, the regulation needs to set obligations to RES generators to provide Ukrenergo the data needed in a consistent way.

Monitoring the generation and flexibility adequacy for ensuring system security

With the increase of RES integration, Ukrenergo is required to have sufficient flexibility in the system available to maintain the short-term adequacy of the system. With increasing RES shares, Ukrenergo may face flexibility adequacy issues due to the combined effect of a) increasing need for flexibility due to RES variability and b) decrease of "supply" of flexibility as flexible peaking plants are shifted out of the market as zero marginal-cost RES supply part of the system energy (RES merit order effect). Remaining large-scale nuclear power plants as well as RES plants do not provide sufficient flexibility to cover the gaps. **A high amount of flexible capacity will be needed in the future to support the system operation with RES**.[2]

In order to assess the issue of adequacy and flexibility, Ukrenergo is recommended to **develop own processes and tools to implement the adequacy assessment calculation** according to the ENTSO-e methodology and applying probabilistic approach (Monte-Carlo) to calculate the short-term adequacy on different time frames (week- to day-ahead and intraday). This rolling assessment captures the impact of increasing accuracy of RES forecasts closer to real-time and will help Ukrenergo to avoid over- or under-dimensioning of the flexibility needs. These tools should be supported by the establishment of in-house data infrastructure and automated data management processes that will allow the sequential application of the assessments. In the figure below, an overview of the inputs needed for the adequacy assessment process based on the ENTSO-e recommendations.

The solution for flexibility resources should optimally be market-based. Ukrenergo is recommended to **review the market design of the ancillary service market and its interaction with other market segments** to ensure sufficient liquidity in the balancing market. The review and development of the market should be realised closely with the regulator and the market participants. For this, the ancillary service market design should penalise the market participants creating imbalances and award the service providers properly. Proper price signals will attract more market participants to provide balancing services and increase liquidity. Additionally, the market design shall enable the market entrance of small flexible units such as batteries, RES, demand response, and aggregators in order to increase the competition in the market and increase the availability of resources to do intraday imbalance management. However, till the **required liquidity is achieved, Ukrenergo should properly monitor the development of the system flexibility adequacy and if needed propose solutions under regulated mechanisms to ensure system security**. Flexibility and related recommendations are further discussed in details in Section 7.

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[2] Ukrenergo indicated the need of at least 2GW of flexible peaking gas power plants capable of performing multiple start-ups and shut-downs per day till 2025 for balancing purposes.

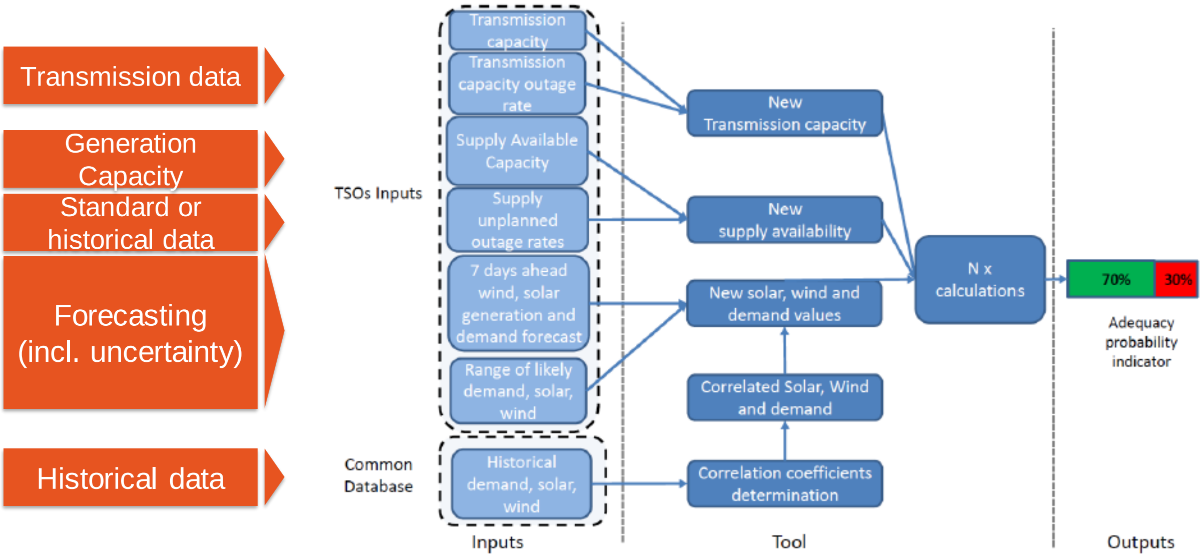

Figure 13: Example of an ENTSO-e conforming adequacy assessment flow chart (ENTSO-e)

6 TSO Positioning & Strategy

The TSO is a key stakeholder and should evolve to the “enabler” of the energy transition. The system transformation brings radical changes to the classical TSO activities of asset ownership and system operation. Furthermore, new activities are added such as the role of the market facilitator, while at the same time the TSO should manage and implement the high level of grid investments in a relatively short period. International experience shows that this implies major adaptations to the TSO corporate structure, strategy development, communication, public relations, investment planning and business model. **The system transformation on the one hand will require a change in organization and functions within the TSO, and on the other hand allows the TSO to evolve to the central role of the trusted public advisor and enabler of the energy transition.**

Ukrenergo could benefit from positioning as a trusted public advisor in the discussion of the sector development by studying a set of political scenarios and the resulting need of grid development. A key challenge is to provide an independent assessment of the policy targets from the perspective of the TSO and help the government to set the agenda to the right direction. Further internal challenges, as the organizational structure and activities, improvement of effectiveness, and new activities related to public acceptance and digitalisation provide the opportunity to position Ukrenergo as a key player of the energy transition.

Organisational growth and adaptation: a radical transformation for the TSO

Traditional TSO business has limited uncertainties due to the established situation and stable environment. The energy transition with the ambitious target for RES integration disruptively changes the old business model and makes the business environment of a TSO uncertain. Ukrenergo’s current organisation is aligned with TSO’s classical business units such as market, system operation, grid investment, grid operation, company management.

With the transformation towards a RES-focused system, **Ukrenergo is recommended to review the current organisational structure** with regards to its capability to forecast future developments and to be agile in different situations of the business. Ukrenergo needs to secure sufficient in-house competencies to understand and shape the development of energy transition. This means practically the reinforcements of existing teams with new competencies or development of new teams elaborating with new topics. Examples of such reinforcements are as follows:

- System Planning Team: Reinforcing with expertise in HVDC, offshore grid development, system stability analysis, FACTS, market modelling, data management, etc.
- System Operation Team: Reinforcing with competencies in mid-term planning, data management, RES forecasting, innovative system operation concepts, etc.
- Regulation Team: Organizing all regulatory activities in one Regulatory Affairs Department is due to the increasing regulatory pressure and its impact on the Ukrenergo’s revenues. A single department ensures no overlaps or roles and responsibilities within the company and increases transparency. Further, the new department of Ukrenergo would require resources from different fields such as economist, engineers, lawyers and political scientist.
- Digitalisation Team: Developing a new team working on the company’s strategy and implementations of digitalisation topics in order to make Ukrenergo becoming a digital TSO

These practical examples show how Ukrenergo’s organisation can be changed in the short- and mid-term. Accordingly, the amount of resources will grow in some dedicated team according with the new tasks and requirements for system development and the adoption of new technologies.

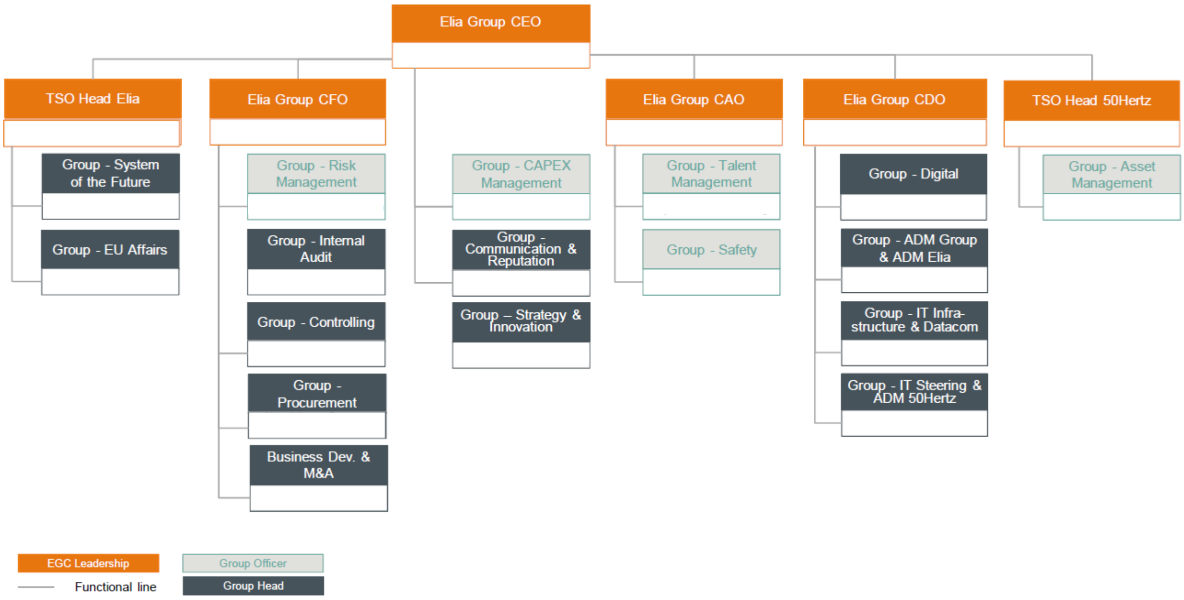

Figure 14: Example of a modern TSO organisation in the Elia Group

Strategy development and scenarios

The uncertain business environment requires Ukrenergo to identify the increasing uncertainties in the energy landscape and the need for an active steering and positioning of the TSO. For the realisation of that task, **Ukrenergo is recommended to create a strong Strategy Planning Department to anticipate emerging issues in the TSO landscape and important future trends, take action and shaping the policy environment.** The strategy planning department needs to implement a standardized strategic planning process with clear milestones and deliverables aligned with the other planning processes (e.g. business planning, budgeting). Adequate Key Performance Indicators (KPI) needs to be defined by Ukrenergo to measure the strategy's success including the targets related to the RES integration. Defining the KPIs is challenging and often needs a trade-off between different goals. [3]

By identifying basic trends and uncertainties, the TSO is able to construct a series of outlooks that will help to identify the no regret actions for implementation in the company and the specific actions to be analysed to support the company's vision. Thus, **Ukrenergo is advised to derive its own scenarios,** which may include but not need to follow the government scenarios, by anticipating future developments. The scenarios represent directions rather than precise and detailed development states. **It is recommended to outline the scenario concept and scenario descriptions in a strategic scenario planning handbook.**[4]

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[3] In this respect, Ukrenergo has just reinforced in February 2020 the Strategy Planning and – Development Unit by forming the Strategy Planning and Analytical Department, which consists of three separate teams with 19 staff members in total. This step is well aligned with the recommendations given in this paragraph. The new department would give Ukrenergo the needed people and knowledge to develop a strong strategy to be successful in the uncertain business environment in the next years.

[4] Ukrenergo already made the first steps in strategic planning with scenarios included in the new company strategy 2020 – 2029, which was in preparation at the time this report was drafted. This new company strategy is developed based on three different scenarios, based on assumptions related to the modern world trends, trends in the energy sector, sector development concepts and most relevant TSO's targets. These scenarios represent directions and brief development states in each element of strategy.

This approach enables Ukrenergo to **decide on the scenario to follow and develop a roadmap for this scenario including no-regret actions to ensure the direction towards this vision.** For example, the goal would be to act as a facilitator of the decentralisation meaning to make happen the wave of new technologies such as Solar Photovoltaic (PV), Electrical Vehicles and Energy Storage expected before 2025; and harvest the opportunities given by the energy transition through developing new infrastructure until 2030. In the figure below, the key elements of such a scenario analysis for Elia Group is presented, where four extreme scenarios are developed across the two main trends of EU integration and decentralisation.

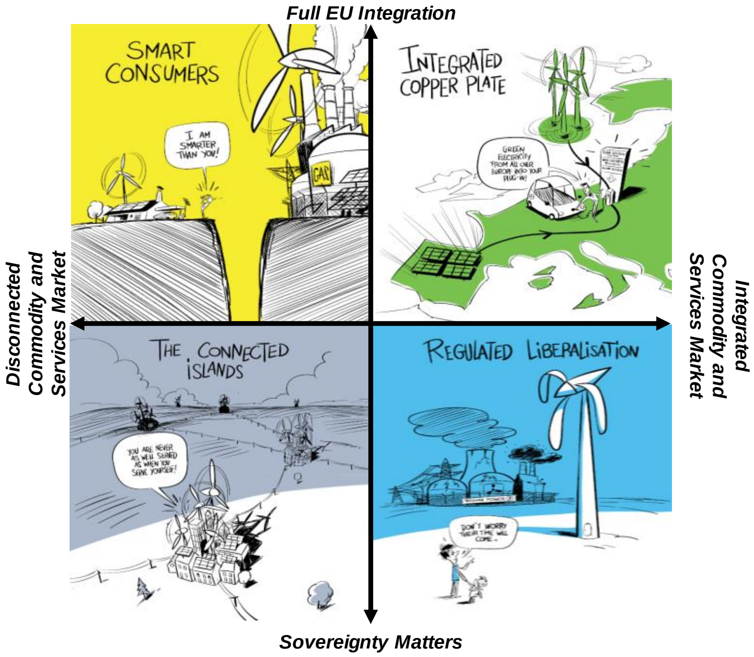

Figure 15: Possible scenarios in the TSO business defined by Elia Group Strategy Development Office

EU regulation impacting the TSO strategy

With the ambition of ENTSO-e integration, Ukraine should align to EU energy targets defined in the clean energy package (CEP) at the national level with very ambitious goals for RES integration, CO2 reduction, energy efficiency, and providing interconnection capacity for cross-border trading. An overview of the evolution of the 2020 targets to the new 2030 targets under CEP is presented in the figure below. Ukrenergo should anticipate and align those targets with the company's objectives, strategies and concrete strategic actions with regards to: a) Cross-border trade, b) Regional cooperation, c) Flexibility, d) Consumer protection, information and empowerment, e) Investments. It is recommended to develop adequate KPIs to translate EU CEP targets into company's objectives, strategies and concrete strategic actions.[5]

[5] According to feedback from Ukrenergo, adequate KPIs to translate worldwide trends and targets into Ukrenergo strategy have been formed and included into draft of new strategy 2020-2029.

	Previous EU targets 2020	New EU targets 2030	
CO_2 Reduction of emission[1]	20%	40 %	*Target agreed at the level of the Heads of state and government*
Renewables Share of energy consumption	20%	min. 32 %	*EU-level binding target*
Efficiency Reduction of energy consumption[2]	20%	min. 32,5 %	*EU headline target*
Interconnection	10%	15 %	*National target*

1 compared to 1990 levels (ratification of the Kyoto protocol)
2 compared to 2008 levels

Figure 16: List of EU Targets by 2030 set in the Clean Energy Package

Public acceptance as a key driver for the RES integration

Ukrenergo improves its image in the society by creating more transparency, committing on anti-corruption and compliance, developing corporate social responsibility program with many engagements for the society, and reducing the environmental impact of their business activity. These activities are important for the TSO's public acceptance. As a result, the majority of the publicity accepts the key role of Ukrenergo in the energy transition and understands the need of grid development in the energy transition. Low resistances for new grid projects are observed thanks to a transparent and open communication. However, Ukrenergo should be aware that this situation can change rapidly, when the RES penetration is high causing needs of building new wind turbines and new lines across the country to integrate efficiently renewables.

Ukrenergo is recommended to **develop a transparent, open, bidirectional and standardized communication and public stakeholder management strategy** in order to strengthen the public acceptance. Concretely, Ukrenergo needs **to focus on early public participation approach and develop a Toolbox and Standard for public relation works.** For example, sharing information on an internet platform can be one building block within the set of the Toolbox & Standards at Ukrenergo. Other possible tools are expert dialog, driving dialogue van to the town affected by future grid project to seek actively dialogues with the affected community, etc.

On the technical side, Ukrenergo needs to **continuously develop new initiatives and innovations** applied in grid projects, which **reduce the impact of the new project on the people and the environment** (e.g., new pylon design, vegetation development concept, etc.).

Financing of the grid investments is another key topic for the realization of the energy transition. It is important to maintain a clear communication of the total investment volume that will be needed in the future with the public. With the **increased transparency**, the **public can understand better the cost intensity of the energy transition and the financial impact of each grid development measure from Ukrenergo**.

Additionally, important partners of the energy transition and the TSO are non-governmental organisations (NGO). A trusted relationship with NGOs and a concerted understanding of the need of transmission projects for the energy transition brings mutual benefits. The position of the TSO towards the ministry would become stronger when having NGOs on the same side supporting the argumentation. Therefore, **Ukrenergo is recommended to develop a trusted relationship with NGOs towards the common goal of implementation of the energy transition**.

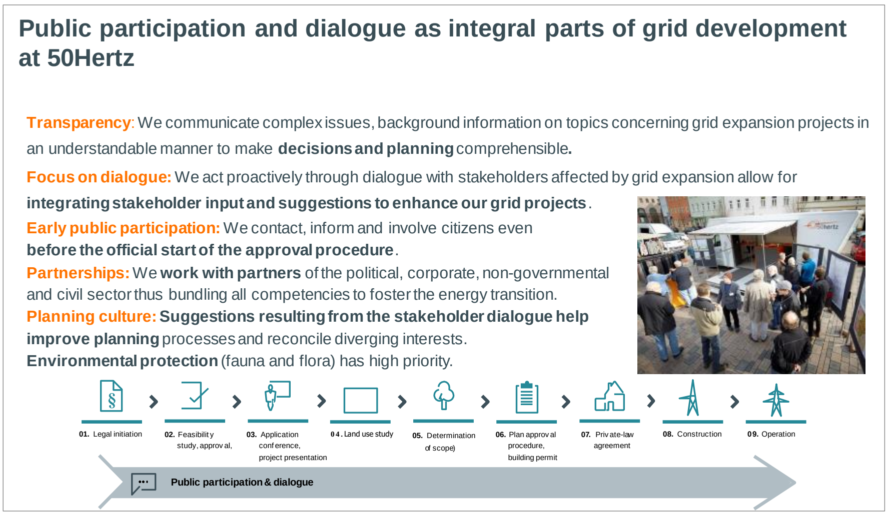

Figure 17: 50Hertz's approach of public participation process

7 Market Design & Flexibility

Market development plays an increasingly important role in the strategic planning of a TSO. In traditional systems the market dynamics are limited due to strong regulation. RES introduction brings radical changes to power market design as it impacts the market in various ways, such as reducing market prices, increasing price volatility and the reducing profitability of conventional generation. The TSO should play an important role in all market design as the institution that can assess the impact of market development on the power system operation. The TSO has to actively participate in the market design discussions and present valuable propositions from the perspective of the system operator. This include the design of the energy and balancing market, the role of new and small market players, and further the need of interconnection and market coupling for ensuring security of supply and maximizing benefits of RES uptake. By doing so, the TSO can prevent any negative impact from the market develop on the system operation.

Ukraine introduced the competitive electricity market in July 2019, and from then on electricity can be traded bilaterally on the long-term or via a power exchange for the short-term. For the marketing of renewables, the Single Buyer model is established and RES generators are paid with the feed-in tariff (FiT). Furthermore, RES auctions has been selected as support mechanism (‘green auctions’ introduction 2020). With the introduction of the competitive market, balancing and ancillary service market are also put in place for the market-based procurement of system services. Additionally, the Balance Responsible Party concept has been introduced as stated in the market rules. However, key processes as prequalification, market operation and settlement are still under development.

Ukraine is working on the ENTSO-e connection in order to increase its electricity exports to other European countries. In a next stage, the Ukrainian power market can be coupled with neighbouring ENTSO-e members. On the one hand, this could allow Ukraine selling electricity to European countries. On the other hand, the balancing market can be integrated with neighbouring balancing markets in order to reduce the size of balancing capacity reservation, and to reinforce the competition in the market.

Furthermore, digitalisation is a cornerstone in the strategy of Ukrenergo. Ukrenergo has made the first steps towards the digitalisation in the energy dispatch, system operation, and enterprise’s resource management. Moreover, the company has developed different projects in terms of cyber security and is highly interested in other topics related to unmanned substation, predictive maintenance, smart grid, big data, artificial intelligence, etc. which will have a strong impact on the business. A digital strategy helps the TSO to understand and prioritize new technologies and their implications. The adoption of a digital strategy will have advantages for the company and lead to a transformation process by enhancing efficiency, flexibility and brings new business opportunities outside of the regulated system.

The following section provides detailed view on the diverse gaps in “Market Design & Flexibility” supporting Ukrenergo on the transformation towards higher shares of renewables.

EU market design implementation: Market coupling

The establishment of a Pan-European energy market aims on providing secure and affordable energy to all citizens. European interconnections and common market rules enable integrating and managing RES variability on a continental scale leading to price convergence among European countries. As a consequence, local generation will be in price competition with European generation. Market coupling comes along with increased cross-border energy exchange. **Establishing a functional market coupling will support the business case for RES in Ukraine and increase energy exports.** Hence, **interconnection infrastructure and market coupling between Ukraine and ENTSO-e member states are an enabler for the RES integration in Ukraine, and the implementation of the market rules through stable market design is crucial for its success.**

Coupling of markets allows for benefiting of lower electricity prices in other countries or higher export of locally available electricity. Market designs between different countries need to be aligned. However, markets need to work first effectively on national level before being coupled. **For Ukraine, before establishing price coupling with cross-border energy markets, the local day-ahead and intraday markets have to function with regards to the legal, contractual and technical requirements.** In general, asynchronous coupling with ENTSO-E would be possible via HVDC links or back-to-back connections as it has been in the past for the Central European coupling with the Nordic area.

The implicit allocation of cross-border capacity through matching of the most competitive energy bids and offers leads to benefits such as increased liquidity and reduced risk for energy traders related to trading losses. However, the development and implementation of the implicit allocation algorithm have been a challenging process at ENTSO-E: the algorithm is now operational and expandable to changing requirements. **For Ukraine, a gradual transition from explicit to implicit capacity allocation could be envisaged.** The implementation is challenging with regards to the performance and scalability of the algorithm that needs to manage the growing number of connected market and its technical requirements (TSO requirements, grid topology changes, geographical extension etc.).

Cross-national collaboration among energy markets is prerequisite for a functional price coupling. Areas with more than one energy market can be coupled with monopolistic energy markets (area with one market) as long as the principles of a market-based, non-discriminatory and transparent market access is guaranteed. **The role of Ukrenergo for the market coupling is crucial regarding the needed close collaboration with other TSOs**: For Day-ahead market (DAM) coupling TSOs are responsible to calculate cross-zonal capacity and allocation constraints and provide them to the National Electricity Market Operators (NEMOs) until the day-ahead deadline, and then the NEMOs are responsible to operate the Single Day-Ahead Coupling. The NEMOs have also further responsibilities related to the contracts with market participants and physical and financial settlement of volumes exchanged on a border.

Coupling of energy markets would be dependent on a **harmonization of procedures and rules** among them for proper technical functioning and complete economic benefits. For example, all markets should be bound to a uniform market gate closing time while gate opening can differ between markets. The harmonisation target should be constantly taken into account while developing and amending the market rules.

The number of competitors need to increase, either internally or through interconnection or definition of bidding zones (Scandinavian model). Decisions on support mechanisms for small players need to be carefully considered as hidden subsidies could send wrong market signals. Negative prices penalize inflexible generation and incentivize new investments in flexible solutions**. Improving liquidity should be the key target for the market introduction in Ukraine.** The role of the TSO is key as the availability of transmission infrastructure plays an important role in increasing the numbers of competitors.

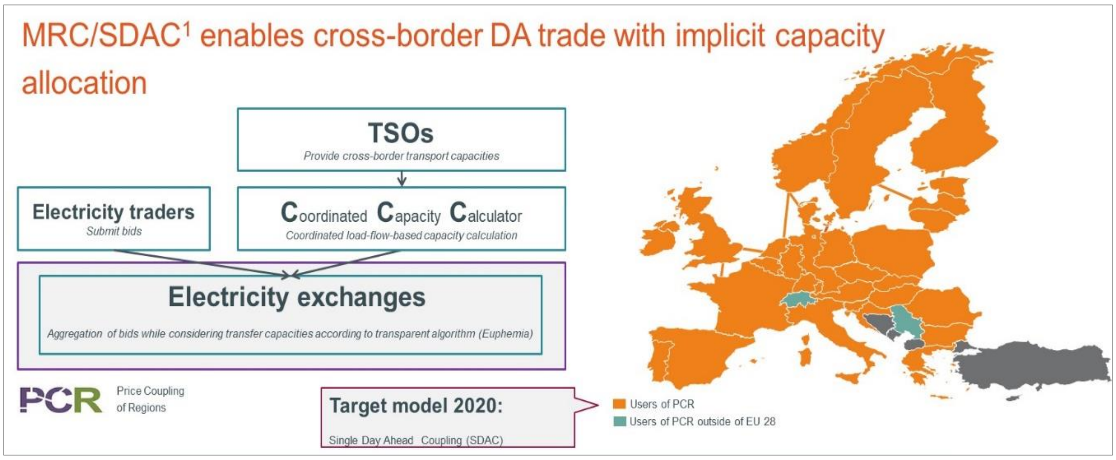

Figure 18: DA implicit price coupling in the ENTSO-E system

A key strategic topic is related to the **bidding zone configuration**: Defining the bidding zones is a complex process and often bound to political country interests. It impacts the market outcome and the physical flow and the need of redispatch respectively (change of generation dispatch after market closure to solve grid bottlenecks). Zonal pricing and nodal pricing differ in the process design for congestion management. Liquidity advantages of zonal pricing supports the market integration of RES. However, the decision on number of bidding zones is ultimately a political decision. **Potential bidding zone configurations in Ukraine could be identified taking into account future RES expansion scenarios.** As the bidding zone configuration will define the grid development and market outcomes, key factors to consider should be the expected social welfare gains against liquidity impacts. This should be done based on a process of assessing different indicators (e.g. based on capacity allocation and congestion management (CACM) regulation), and by outweighing the alternative grid expansion solutions.

Generation Adequacy and Capacity Mechanisms

Due to the large share of inflexible generation, one major challenge for Ukraine will be the management of situations of low demand and high RES infeed. As a result, more flexible generation is needed with increasing RES shares. Furthermore, RES generation cannot fully displace conventional capacity as renewables are weather-dependent and thus not controllable. Generation from transmission interconnections or controllable conventional units are needed to ensure system adequacy at hours with high energy demand and low renewable infeed. **The development of solutions for adequacy in Ukraine will be dependent on the level of energy exchange through interconnection with neighbouring countries, where the ENTSO-E interconnection could become part of the solution.**

Renewable generation impacts market prices and reduces profitability of power plants, in particular of (flexible but expensive) peaking units. Adverse effects that could happen are early shutdowns of conventional units or lack of incentives for new investments leading to a generation adequacy problem. In Europe, Capacity Remuneration Mechanisms (CRM) are currently intensively discussed to ensure national and Pan-European generation adequacy without adverse effects on competition. In Ukraine, with increasing share of renewables, the generation mix should evolve towards higher flexible generation technologies, and already faces today risks due to inflexibility of generation, mainly driven by nuclear and hydropower stations**. Ensuring generation and flexibility adequacy in the Ukrainian system will be a major challenge and capacity markets could be considered for later stages in RES development**. However, the capacity market designs are diverse, and all solutions have significant disadvantages. Generally, no market-based system can ensure the full system adequacy, and the implementation needs to be carefully assessed with regards to the impact on the existing market, in particular avoiding distortion of competition, impact on long-term price signals for investors and promotion of demand-side-management; and in accordance with national laws and European regulation.

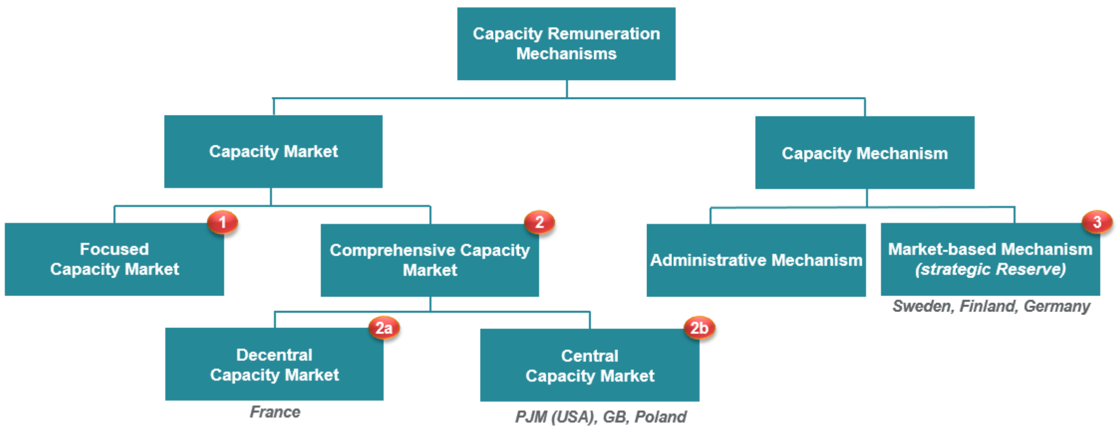

Figure 19: Structure of Capacity Remuneration Mechanisms

Balancing market and ancillary services: key for ensuring a secure transition

General challenge for the system operator is to control the balance between consumption and generation to ensure a frequency of 50 Hertz. TSOs are in charge of resolving residual imbalances in real-time and operating the balancing market. **Here, the balance group concept, with the Balance Responsible Party (BRP) as responsibility, is supportive for successful RES integration as market players take responsibility for the system balancing**. [6]

Key conditions for the effectiveness of the BRP concept are (a) the imbalance prices should be high enough to incentivize market parties to be balanced and (b) no market parties are excluded from balancing responsibility. **For Ukrenergo, the right market design can increase efficiency resp. reduce imbalances if the market participants (BRPs) are financially incentivised to remain balanced.** Critical points are a single balancing responsibility, 15-min metering, unlimited portfolio bidding in each bidding zone, clear settlement rules and punishment of all forms of 'gaming' (strategic behaviour of market players detrimental to the market efficiency and security of supply). Imbalance prices shall incentivize to minimize imbalances, i.e. gaming with wholesale prices should not be profitable for the BRP. A proper price setting incentivises market players to reduce imbalances by improving accuracy in load and generation forecasts, by using and further developing demand and generation flexibilities within the BRP portfolio and by increasing short-term trading to resolve imbalances.

For the integration of larger shares of renewable energies in Ukraine, the balancing market design requires adjustments for the participation of RES. Several effective measures were implemented in the German balancing market in order to improve participation of RES through procurement close to delivery (to allow improved forecasting and higher guarantee of availability), through allowance of aggregated distributed resources (pooling reduces uncertainty and through small bid sizes to allow higher participation of distributed resources and through the15 minute settlement period. The Ukrainian market design should be adjusted accordingly to support RES integration. These adjustments could be introduced in phases according to the RES deployment rate. As shown in the figure below, the evolution of the balancing market design in Germany led to an overall reduction of the reserve requirements, in a period of high deployment of RES in the system.

The balancing market design should be reviewed to ensure sufficient liquidity in the balancing market, with key elements the application of strict BRP control, universal application of BRP model (including RES generators), proper pricing of imbalances, enabling the market en-trance of small flexible units.

The TSO should be prepared to prequalify a large number of generators. One proven solution in Germany has been an IT platform developed by the TSOs to handle the high amount of prequalification requests caused by higher participation of small-scale distributed resources. The platform provides the necessary documentation such as general requirements, reports, rulebooks; and allows managing the prequalification processes digitally. **Ukrenergo would benefit from developing and operating a similar balancing platform for the efficient prequalification, operation and monitoring of the market.**

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[6] Balance Responsible Party (BRP) refers to a market participant or its chosen representative responsible for its imbalances in the electricity market. A balancing group is a collection of assets (generators and loads) for which the BRP is in charge of maintaining a physical balance between power feed-in and off-take in each market time unit. This design leads to a reduction of over- and underproduction in each group by transferring the financial responsibility of energy imbalances to the market participants. Each BRP takes actions to reduce power deviations either by adjusting infeeds within the group or by trading on the short-term energy market. The remaining (residual) imbalances are solved by the TSO in real time through the activation of balancing reserves. Each BRP is charged for their imbalances based on the TSO imbalance energy procurement costs.

Important is to ensure transparency and access to the market rules and market data. The development and operation of this platform requires significant resources from the TSO.

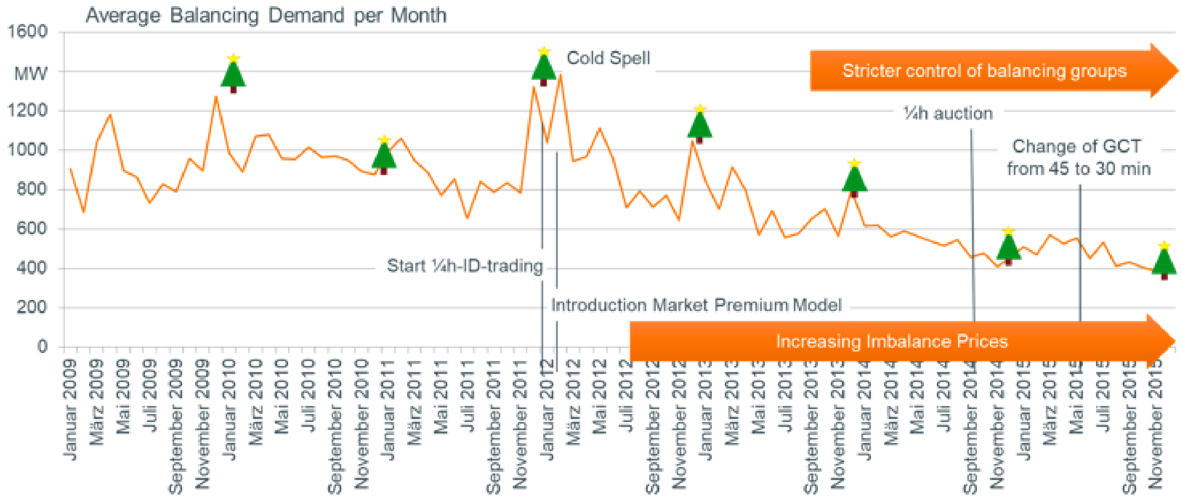

Figure 20: "German Balancing Market Paradox" – although RES increased the "demand" for flexibility, market design adaptations led to a reduction of the reserve requirements

In Germany, the requirements for the monitoring of ancillary services are conditions of the contract for the service provision. The requirements should be transparent and part of the prequalification process. A rulebook is available on the German control platform. Generation units can provide one or more services (black start, control reserves etc.). **With the integration of balancing and ancillary service markets, the management of an increased number of market participants becomes a challenge of Ukrenergo**: the provision of services requires correct monitoring. The provider must fulfil the increased measurement requirements and bear the cost. Therefore, the requirements must correctly be defined upfront for the prequalification process. Further, data collection is a complex task that needs to be managed efficiently, for example 15minute imbalance quantity and prices, but monthly settlement.

Digital Transformation and new roles of the TSO in a "prosumer centric" future

Energy transition is characterized by a high penetration of renewables and a fundamental paradigm shift towards "demand follows generation". This transition both changes the system vertically (TSO-DSO) & horizontally (TSO-TSO) bringing challenges of decentral flexible participation and maximization of infrastructure use. Energy transition implies a change from few large power plants to hundreds (German case: millions) of small generation units located both in distribution and transmission level. Local abundance of renewable generation will invert power flows from DSO towards TSO and requires a higher energy transportation on transmission level. **Maximizing green energy consumption in Ukraine would entail flexible solutions on generation and demand side, and additional grid infrastructure to ensure adequacy.**

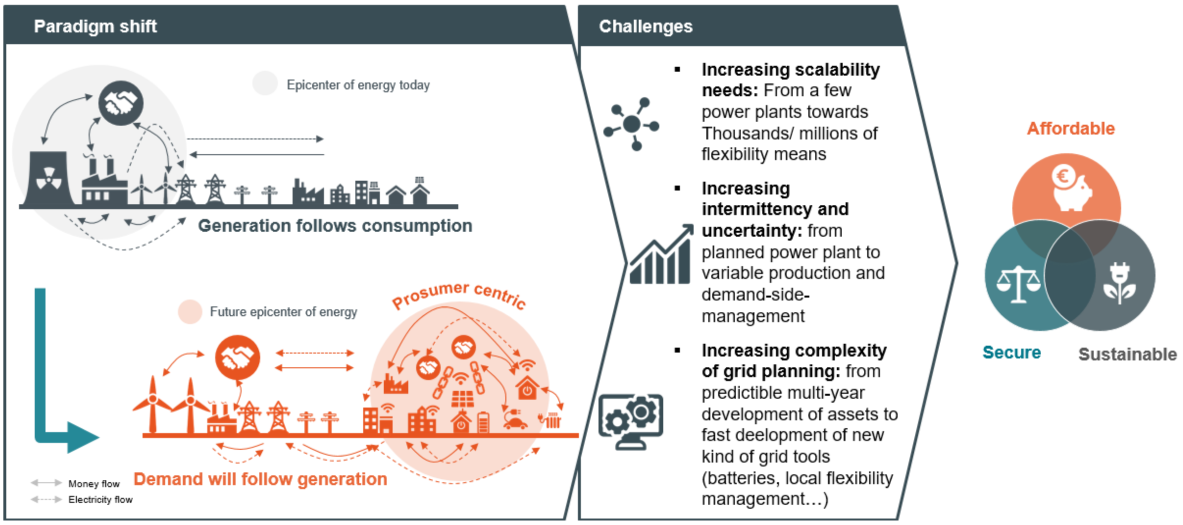

Figure 21: Fundamental shift towards "demand follows generation" at high penetration of renewables

Digitalization creates new products on the demand and supply slide enabling the participation of new players to the energy market. The TSO as a market facilitator allows for reduction of flexibility costs and new products increasing the participation of a maximum of players to the energy market. Digital asset solutions also enable the reduction of costs and increase of energy security (e.g. less human errors). **Ukrenergo has the opportunity to increase efficiency and enable the energy transition through facilitation of these market developments (Digital TSO).** Furthermore, new digital solutions can improve efficiency in system operation through automations and decision-making, and can manage the higher volatility and uncertainty of renewable generation.

Support from the top management in Ukrenergo is a key success factor and needs to be established from the beginning of the innovation process. A clear governance structure is a prerequisite taking into account cross-functional teams in order to create awareness and business knowledge; defined KPIs complement the creation of trust with the management. Innovations typically encounter reservations and rejections from the people who are impacted. Further, **establishing an innovation culture is the basis for success.** Constant communication through all communication channels (bilateral, intranet, events etc.) of the company, among teams and employees is needed to change the image of innovation.

The understanding of innovations and its benefits for the business is the first step. Further, the alignment with business/department strategies and the separation of innovation activities from business activities are required. Clear validation processes for new technologies/use-cases support the transfer of innovations to the business. **The innovation process would require a roadmap and structured approach, meaning an alignment with the strategy of Ukrenergo and a validation process supporting the transfer of new technology to the business.**

8 Structural Reforms: Regulation & Finance

The regulatory environment in Ukraine is in high transition: the single buyer model is abandoned and competitive wholesale market has been introduced accompanied with changes in the regulatory regime. Currently, grid investments are regulated by a cost-plus mechanism, and TSO ownership unbundling is planned. Target is the evolution towards incentive-based regulation in 2020-2021.

The introduction of RES should be properly considered as it becomes a key driver for the TSOs' Capital Expenditures (CAPEX). Hence, the TSO shall actively shape the regulatory framework by active exchange and communication with relevant stakeholders. One key challenge is to identify and understand the critical elements of the regulatory framework and their impact on the investment budgets. Afterwards, the TSO shall include these in the planning processes.

The regulatory framework in Ukraine is defined at national level by the ministry. However, Ukraine will have to align its RES targets with the EU while targeting the ENTSO-e integration. The regulatory framework of the EU will increasingly become the frame of the Ukrainian regulation. Since the RES targets directly impact the TSO business, Ukrenergo would need to actively apply the EU targets on the national context. The result can be consulted with the regulator and other stakeholders. Also the communication and exchange with EU institution like ENTSO-e and Agency for the Cooperation of Energy Regulators (ACER) will be important for Ukrenergo and the National Energy and Utilities Regulatory Commission (NEURC).

Until now, attractive FiT could lead to an 'over-development' of RES. The implementation of green tariffs in 2008 increased renewable energy producers' subsidy to around 23 Euro cent/kW, which is around 8 times higher than the non-renewable wholesale price. Producers of solar power receive the largest subsidy of between 34 and 43 Euro cent/kWh. Due to the attractive condition from the green tariffs, many investors intend to build new plants. Ukrenergo has received many connection requests for RES up to 11 GW. In the next step, Ukraine aims to introduce green auctions in 2020 in order to better control the development pace of RES. It shows that incentive mechanisms shall be set appropriately depending on the development stage of RES in the country so that it does not stop the energy transition on the one hand, but also keeps the energy transition affordable for the society on the other hand.

The fast development of the renewable energies creates an amount of connection requests although connection capacity of the grid is limited and grid expansion for the transport of the electricity is needed. Since RES generators have priority connection and access, their connection to the grid still depends on the current capacity and condition of the grid. Due to capacity limitation, innovative connection concepts and corresponding regulatory measures, as outlined in the following section, shall be developed so that the connection can be realised quickly without having a strong impact on the system reliability of the RES hotspot regions.

The following section provides detailed view on the diverse gaps in "Regulation & Finance" supporting Ukrenergo and Ukrainian authorities on the transformation towards higher shares of renewables, focusing on technical regulatory measures for integration of renewables in the grid.

Grid financing & regulation

Incentive regulation framework decouples revenues from costs, meaning the TSO's revenues are fixed for the next 5-year regulatory period, stimulating efficiency improvements (Profit = revenues – costs) if the system operator manages to increase the efficiency and thus cut more costs than laid down by the regulatory authority. The system operator is allowed to keep this extra profit during the regulatory period. **An incentive regulation scheme would stimulate efficiency improvements for DSOs and TSOs in Ukraine.**

However, incentive regulation is suitable for ‘stable systems’, meaning predictable reinvestments in the existing infrastructure and maintenance expenditures. As numerous investments have to be made due to the integration of renewables, exceptions/adaptations for such growth-related investments are indispensable. **Hence, the application of incentive regulation in Ukraine would need additional elements to facilitate RES-related grid investments.**

In general some costs are passed through and some are included in an incentive mechanism: for example for grid losses, the TSO can achieve extra profits in case of a higher performance than planned, for instance through better forecasting and procurement. **An application of incentive regulation in Ukraine would need further incentives to rewards the efforts to manage the energy transition.**

The regulatory framework is constantly changing and should be adapted to the changing environment. From the TSO perspective, changes in the regulatory framework can come with effects on the revenues. Ukrenergo should support the adaptation of the regulatory framework through exchange and discussions with the Ministry and the Regulator.

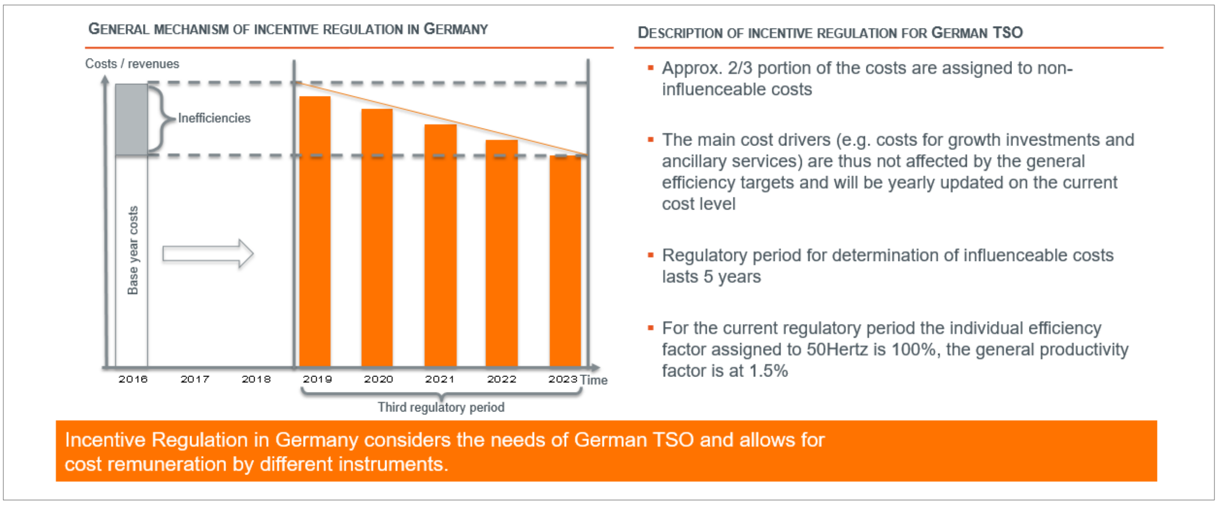

Figure 22: Incentive regulation scheme for German TSOs

RES support schemes

The determination of the RES support scheme is a challenging task. Auctions can be technology specific, based on strict conditions and without policy involvement. The result of the first auction impacts all subsequent auctions. **Hence, it is recommended in Ukraine to apply a well-designed technology specific auction and to retain the design for the next auctions so that the market can adapt and improve**.

Large-scale solar PV are already competitive and are not dependent on a support scheme; under the prerequisites of sufficient grid access and connection. FiT should only be granted to small installations up to 100kW. Feed in Premium should be considered as standard. **The Feed-in-Premium (FiP) model used in Germany could be an option for Ukraine as it is an effective tool for the market integration of renewables**, granted for auctions individually, and should be limited to the full load hours per technology rather than to a granted period. Consider the difficulties that can emerge from the support scheme designs.

The introduction of renewables auctions in Germany, replacing administratively set feed-in premiums, has led to more competition, considerably lower prices and high realization rates. Nevertheless, securing RES deployment at low costs is a product of a wide range of different contractual, regulatory, market, and resource-related factors. The support costs for solar PV declined significantly since the introduction of the auctioning system in 2015 (refer to Figure 23). **It is recommended to base the Ukrainian auctioning design on the German system. Additionally, a differentiation of auctions according to technologies** are necessary**.** For instance, roof-top PV cannot compete with ground-mounted installations, or ground-mounted PV systems are technically less complex projects than large-scale wind farms.

A simple and transparent tendering mechanism is an important success factor. To ensure a high realization rate, it would be important for the Ukrainian auctions to provide **transparent information and to ease the auctioning procedure**. Once designed, the **auctioning system should not change frequently** as the market players need to adapt to the scheme. Auctioning results could fluctuate which is normal and connected to the complexity of wind projects and the technology learning rates.

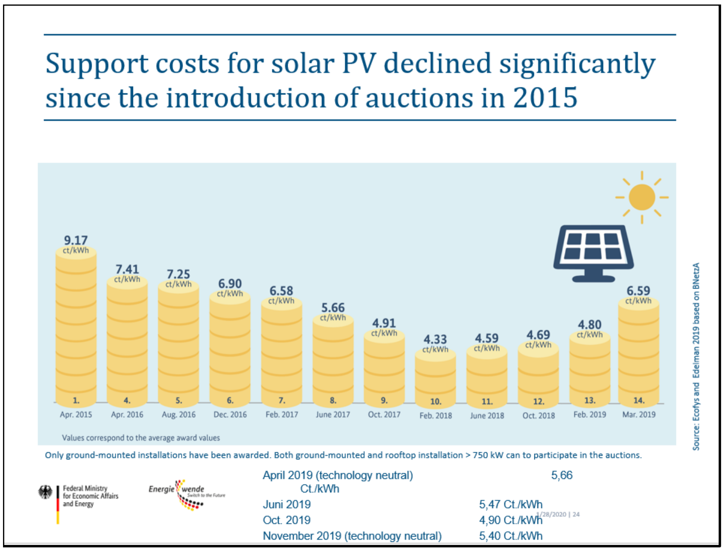

Figure 23: Development of PV support costs in Germany

EU regulation (Clean Energy Package – CEP)

Network Codes and Guidelines are a set of binding rules for the harmonization of technical standards and procedures. The complete integration of the Ukrainian IPS in the ENTSO-E power system means for Ukrenergo to apply and comply new rules and processes. **For Ukrenergo, this integration requires time and demands new resources for the transition phase and the establishment of new roles in the company and execution of new tasks.**

TSOs are mostly concerned with legal acts of the so-called Market Design Initiative of the Clean Energy Package (a revision of the Third Energy Package). The Electricity Regulation aims at fundamentally redesigning electricity markets. Clearly, this also has a major impact on the operation of grids. The CEP entails eight legislative that EU countries have to transpose into national legislation in the coming 1-2 years (until mid-2021). **Fundamental changes in the electricity market design currently represent the main concerns of EU TSOs, and most probably also for Ukrenergo as future ENTSO-E member.**

The TSO has to align with all major stakeholders to ensure the optimal implementation of the EU regulation. Stakeholder consultation processes are very important for achieving consensus and to optimally interpret the regulation to the local conditions. The role of the TSO is crucial for the implementation of the EU CEP on national level. **For Ukrenergo, the compliance with EU rules and standards will require a close dialogue and elaboration with the ministry and regulator**.

The future energy system will be based on renewables and therefore on smaller production units. This requires new and evolving concepts to deal with fluctuating production and growing electricity demand due to sector coupling (holistic optimization of different sectors, e.g. connection of Electricity, Transport and Industry). The new rules from the EU-CEP will promote participation of small players. Hence, **regulation serves as an enabler for small players and an opportunity for Ukraine to benefit from increased demand & generation flexibility; discussion and alignment with all major stakeholders to ensure optimal implementation of the EU regulation will be important for Ukrenergo.**

The current regulatory framework does not have a high consideration for the new and small market players or their aggregators, or players coming from other sectors. The regulatory framework should evolve to allow the optimal incorporation of small-scale resources to the market (e.g. decentralized generation and prosumer concepts) and support the system operation (provision of aggregated flexibility for frequency control or congestion management). Business models should not be based on 'regulatory opportunity' but rather emerge from a systemic vision and long-term economic feasibility. Regulatory changes should follow and enable such viable business models. Key challenge is to position Ukrenergo to become a manager of the energy transition, to develop the systemic vision and test business cases together with the stakeholders from the government and industries.

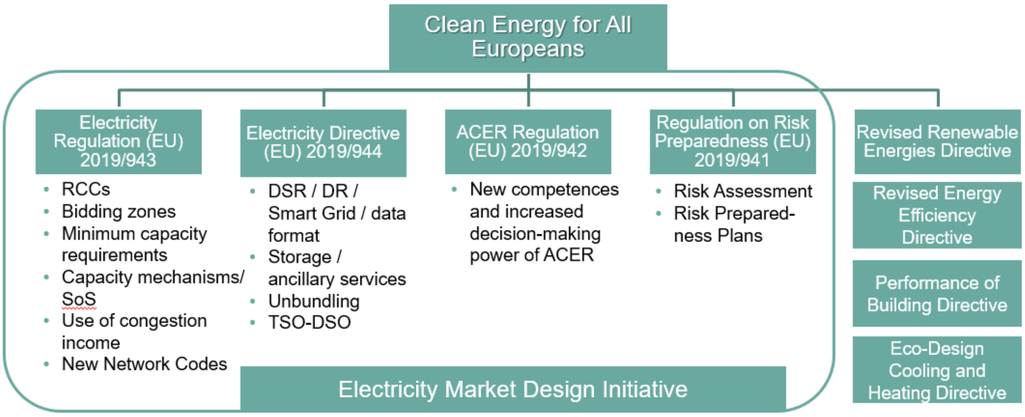

Figure 24: Overview on the Regulations of the Clean Energy Package mainly affecting the TSO

Locational signals & flexible access

Grid access and connection are critical for the efficient integration or renewable energies, and they can be used to steer the RES development. Well-designed technical requirements in grid codes will help Ukrenergo to ensure technical compliance, leverage flexibility and keep security of supply**.** Through the grid code, RES can enhance system reliability and minimize operational costs, for example through higher controllability and measurability and the participation in ancillary services. Further, the grid code allows new flexible market players (incl. demand side) to offer voltage and balancing support. Therefore, **Grid Codes are a critical tool for Ukrenergo to achieve large integration of RES in the system.**

The compliance of RES units to the grid codes' technical requirements needs to be checked and verified. An independent certification institute ensures an objective and transparent certification. The grid operator will approve the connection process based on the certificates. **When a new RES production unit applies grid connection, Ukrenergo must assess the available grid capacity before making a connection and allowing access to the grid, through well-managed formal processes and contracts.**

Locational signals could allow internalizing grid investment costs in the deployment of RES capacities, to ensure alignment of the RES deployment with the grid development. The RES auctioning process could incorporate the best location & RES capacity based on several criteria such as potential, effective land use, distances and grid identified in collaboration with various stakeholders. **The renewable auctioning in Ukraine could take into account pre-selection of best localizations with regards to the grid potential. Alternatively, the incorporation of locational components in the RES support**

schemes could be considered. Challenges are the realization of a transparent and official auctioning process, the need of adequate political support and the acceptance by the public.

Locational signals in transmission charges are able to reflect investment costs related to physical network and the need for additional connection capacity. Locational signals improve visibility towards additional need or savings in transmission investments. **Ukrenergo could use locational signals in transmission charges in order to internalizing costs of grid investments and incentivize generators** to locate their power plant where the existing grid can accommodate the additional generation capacity with no or minimal additional investments.

Flexible access is the way to optimize current infrastructure by using 'flexible access criteria', for example through a contractual agreement on reduced grid access in emergency situation. Benefits are less connection delay for producers (benefit for RES developers) and postponing or even avoiding additional network investments (benefit for tariffs/customers). **Flexible access represents one solution for Ukrenergo to optimize current infrastructure and accelerating RES integration in spite of lack of full grid capacity**. This means the access is not guaranteed and depending on the grid situation. Further it allows control with respect of the technical limits of the grid. Finally, the flexible access can incentivize new grid users to connect under the condition of a (low) chance of curtailment.

Furthermore, **Ukrenergo should be able to curtail RES units for system security reasons as a last resort measure.** The affected BRP and generation owner needs to be financially compensated for the avoided production. The settlement of the compensation and technical implementation in the redispatch process needs to be established in a transparent manner.

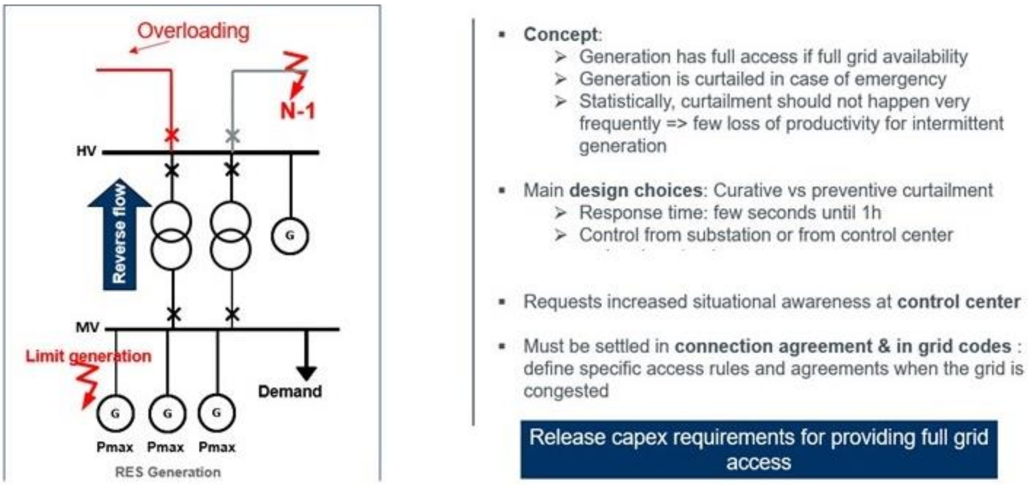

Figure 25: Flexible access concept supporting quick connection and generation with low grid reinforcement

9 Conclusions

In the energy transition towards a green, sustainable and reliable ecosystem, the TSO should play a central role, as responsible for the system integration of RES. The actual Ukrainian power system's situation shows that the country is in a dynamic transitional phase. Ukraine is preparing itself for the connection to ENTSO-e synchronous area. Additionally, the competitive market has been introduced in order to strengthen competitiveness, increase efficiency, with the goal of being integrated into the Pan-European energy market. Regarding the green energy production, Ukraine is also experiencing a fast development in the new installations of RES due to the attractive support scheme. Nevertheless, the Ukrainian transmission system is facing a range of several challenges. Aging power infrastructure, low energy efficiency, high dependence on imports and missing fast-responding flexibilities are some mentioned key challenges. As the implementation of the energy transition is coupled with many additional changes and challenges, the TSO should be prepared properly in advance in order to perform well in its role as the enabler of the energy transition.

Five expert workshops have been organised, covering the five main building blocks. By using the key lessons learnt from 20 years of RES integration in Germany as starting points, the discussion of the lessons learnt and the current situation in Ukraine during the workshops enabled the identification of the respective implementation gaps. The bottom up gap identification was further synthesized to the present gap analysis report, identifying the opportunities and optimization potential for Ukrenergo, and lately the challenges to integrate RES in Ukraine in a sustainable and secure way. The key gaps from the TSO perspective are mapped according to the five building blocks:

1. ***System Transformation and Planning: managing the RES-driven infrastructure development***:
   - Adoption of **scenario planning methodologies** tailored to the specificities of Ukraine for optimal robust decision making under the high uncertainty characterising the current environment.
   - Evolution of the decision support processes regarding infrastructure development including **data, tools and processes** for optimal grid planning
   - **Harmonisation of Ukrainian grid codes** with the ENTSO-e
   - Development of a **long-term strategy for the deployment of interconnectors** to Europe for cross-border trading and reserve sharing
   - Active role of **new technologies to optimize use of existing infrastructure and maintain grid stability** to be considered in the planning process

2. ***Grid & System Operation: ensuring operational security for the system transformation***
   - Establishment of standardised system for operational planning processes and tools and **introduction of an operational planning layer** to support online system operation
   - Implementation of **congestion management and redispatch** planning and operational processes in order to manage the gap between RES deployment and grid development
   - Develop and implement a highly **automated and efficient data management solutions**
   - Implement enhanced methods for **RES generation forecasting** for system operation support
   - Implement advanced **RES controllability and observability** means with the aim to support system stability and increase system resilience
   - Develop processes and tools to monitor **generation and flexibility adequacy** according to the ENTSO-e requirements

3. ***TSO positioning and strategy: transforming the TSO to the enabler of the energy transition***
   - Review the **organisational structure** with regards to the new functions and capacity requirements (grid planning, system operation, energy market, digitalisation, regulation)
   - Reinforce the **strategy development department** to anticipate emerging issues and future trends in the TSO ecosystem and develop clear strategic goals shared with key stakeholders

- Develop adequate **KPIs to translate EU CEP targets** into company's objectives, strategies and concrete strategic actions
- Enforce **public participation and dialogue** as key tool for improving the speed of infrastructure development, involving all key stakeholders

4. ***Market Design & Flexibility: market design to support the system transformation***
   - Establishment of a **proper functioning of the day-ahead and intraday markets** with regards to the legal, contractual and technical requirements.
   - **Price coupling** with cross-border energy markets as a next step with a gradual transition from **explicit to implicit capacity allocation**.
   - Improving **market liquidity** should be the key target for the market introduction in Ukraine.
   - Potential **bidding zone configurations** for future RES expansion scenarios in Ukraine should be analysed, as they will define the grid development and market outcomes. Key factors to consider should be the expected social welfare gains against liquidity impacts.
   - **Generation adequacy** and need for **Capacity Remuneration Mechanisms** should be analysed for the next two decades in line with the future RES projections, coal and nuclear phase out and interconnection development.
   - **The balancing market design should be reviewed** to ensure sufficient liquidity in the balancing market, with key elements the application of strict BRP control, universal application of BRP model (including RES generators), proper pricing of imbalances, enabling the market entrance of small flexible units.
   - The effective prequalification of all the units to participate in the balancing market is a massive work that could place a hurdle to the development of liquidity. **Ukrenergo could benefit from developing and operating a balancing platform for the efficient prequalification, operation and monitoring of the market.**

5. ***Regulation and Finance: Develop the framework to support the system transformation***
   - The application of incentive regulation in Ukraine could stimulate efficiency improvements for DSOs and TSOs but would need **additional elements to facilitate RES-related grid investments** to manage the energy transition
   - Well-designed **technology-specific auctions with stable design** are recommended so that the market can adapt and improve.
   - The **Feed-in-Premium (FiP)** model used in Germany could be an option for Ukraine as it is an effective tool for market integration of renewables
   - The **compliance with EU rules and standards** will require a close dialogue and elaboration with the ministry and regulator, and in particular the changes in the electricity market design due to CEP regulation will set the highest requirements for Ukrenergo
   - **Grid Code is a critical tool for Ukrenergo** to achieve cost-optimal integration of RES
   - **RES Flexible access regulation** represents one solution for Ukrenergo to optimise the use of existing infrastructure and to accelerate RES integration in lack of grid connection capacity
   - **Locational signals could allow internalizing grid investment costs in the deployment of RES capacities to ensure alignment of the RES deployment with the grid development**. The renewable auctioning in Ukraine could take into account pre-selection of best localizations with regards to the grid potential. Alternatively, the incorporation of locational components in the RES support schemes could be considered.
   - **Ukrenergo should be able to curtail RES units for system security reasons as a last resort measure** under a transparent process, with a proper financial compensation of the producer and the BRP for the avoided production.

The presented gaps of the five building blocks form the basis for a thorough identification of the tasks for shaping the energy transition. Concluded, they form the starting point for the development of a future roadmap for Ukrenergo for the system transformation for an optimised integration of renewable energies in Ukraine.

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