





CASE STUDY:

UKRAINE POWER SYSTEM EMERGENCY SYNCHRONISATION WITH THE CONTINENTAL EUROPE POWER SYSTEM

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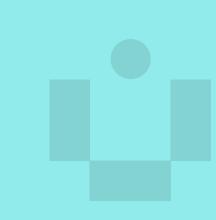


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EXECUTIVE SUMMARY

Ukraine used to be the biggest gas transit country for Europe and was connected to the post-Soviet Unified Power System (UPS) with Russia as the main balancer of the system. The status quo was shaken after Russia invaded Eastern Ukraine and illegally annexed Crimea in 2014. Since then, Ukraine had been determined to decouple from Russian energy sources to mitigate the risk of politically motivated blackmail.

Energy cooperation with the European Union was chosen as the alternative to Russian energy commodities. The first seeds of Ukraine-EU cooperation were planted in 2005 by signing a Memorandum of Understanding which was further prolonged and detailed in a more technical agreement, one of which was an Agreement with ENTSO-E to synchronise their power systems.

By the time Russia invaded Ukraine on the 24th of February, Ukraine didn't buy Russian gas but received reverse gas flows from neighbouring EU countries. The country also made tangible progress in the implementation of the technical preconditions for synchronisation with the continental European electricity grid. On the night the war broke out, Ukraine had disconnected from the post-Soviet Unified Power System to test its grid in isolation, one of the preconditions for synchronising with the continental European grid.

Whether Russia purposefully started a full-scale war on Ukraine on the same day as the isolated mode test (one of the preconditions for future synchronisation), will be reserved as a question for future investigations. Eventually, it led to accelerated implementation of the Catalogue of Measures and emergency synchronisation.

Full-fledged political support and technical feasibility of the project were the main preconditions of the successful accelerated synchronisation. Nonetheless, without the skilful engineers of the Ukrainian Transmission System Operator Ukrenergo and highly responsive dedicated Task Force in the European Network of Transmission System Operators for Electricity (ENTSO-E), the synchronisation would have likely taken years instead of weeks.



The surplus in energy production against low domestic electricity demand created the conditions in which Ukraine requested to launch commercial electricity trade with the ENTSO-E, successfully approved by its members. Thanks to the sale of Ukrainian power predominantly produced from nuclear generation, Ukraine managed to top up the state budget inevitably suffering during the active conventional war.

On 10 October, a massive missiles and drone attack committed by Russia, resulted in Ukraine losing more than one-fourth of its energy generation and hence deciding to suspend exporting electricity abroad. The upcoming 2022-2023 heating season will further test Ukraine-EU energy cooperation and the resilience of the grid.

INTRODUCTION

This paper explores the emergency synchronisation of Ukraine with Europe's electricity grid, which ended Ukraine's dependence on the Russian power grid system and became an unprecedented event in the energy sector. The synchronisation was conducted in extreme circumstances, just 20 days after the full-scale Russian war on Ukraine at the beginning of 2022. The synchronisation was planned to be finished in 2023 but was squeezed into two weeks. The paper briefly describes the work done since 2017 and the preconditions that made emergency synchronisation possible in March 2022. Data sources include in-person interviews, academic articles, reports and official statements of the Ukrainian and EU institutions and agencies.

THE CHALLENGE

Ukraine has a long history of energy relations with Russia. It used to be the biggest Russian gas transmission country to the European Union. Russia broke its image as a reliable gas supplier to Ukraine during the first decade of the 2000s with two particularly remarkable events such as gas disputes in 2006 and 2009 when Russia cut off the gas supply to Ukraine and some of the Easter European countries, causing a humanitarian crisis in the middle of the heating seasons in winter.

Since 2014, the situation dramatically deteriorated – Russia rerouted gas supply through other pipelines, decreasing gas flow through Ukraine to a bare minimum. As of October 10th, 2022, gas transit from Russia through Ukraine remained stable at a low level of 42 mln m3, flowing to Slovakia (36 mln m3) and Moldova (6 mln m3). At the time when the paper was being written, Ukraine was the only Russian gas delivery route to Europe still in use. The Nord Stream 1 and Nord Stream 2 pipelines were damaged by underwater explosives in September 2022, leaving only the Turkish Stream pipeline, which serves southeast European countries with Gazprom gas.

In the electricity sector, for decades, Ukraine was interconnected with the post-Soviet Integrated Power System/Unified Power System (IPS/UPS) of the Community of Independent States (CIS), with Russia as the largest country.



The only part of Ukraine that was isolated from the rest of the country was the Burshtyn Island in South-Western Ukraine. It had an interconnection with the European Network of Transmission System Operators for Electricity (ENTSO-E) and sold the produced power into the European Continental grid.

In 2014, after the Russian invasion of Eastern Ukraine and the illegal annexation of Crimea, the Ukrainian Government took a course toward gradual independence from the Russian gas and electric grid. In the gas sector, it led to the phase-out of direct purchase of Russian gas. In contrast, in the electricity sector, it resulted in the signing of the agreement with the ENTSO-E about future interconnection with the Continental European power systems in 2017.

Since the second part of 2021, when Russia started to build up its military presence on the Russian-Ukrainian border, Ukraine urged to speed up power synchronisation by running a test in isolated mode, which practically means disconnecting from all neighbours and controlling and balancing its system by itself. The test started on the day of the full-scale Russian invasion of Ukraine, which made it obvious that IPS/UPS, with Russia in charge, will not reconnect Ukraine after the test. The data show that Russia and Belarus halted power flow as of 3 pm on 25 February and never restored it.¹

Both gas and electricity dependence on Russia posed an immense risk to Ukraine's energy security. Since early 2022, Russia has been cutting off its European gas clients one by one in response to the European Union sanctions against the aggressor state. Bulgaria, Poland, Finland, the Netherlands, and Denmark were cut off from Russian gas completely, while deliveries to Germany decreased by 40 % and then another 33 % in the run-up to a June 23-24 EU summit, which granted Ukraine EU candidate status.

So far, Baltic countries are still synchronised with IPS/UPS balanced by the Russian grid operator, which incentives Estonian, Latvia, and Lithuania to speed up their disconnection from the post-Soviet IPS. The electricity grid connection with Russia is leveraged in the political influence on Ukraine and its partners and allies. It has already materialised in devastating consequences for the strategic energy infrastructure.

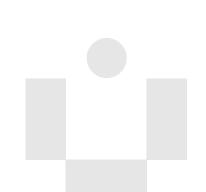
THE SOLUTION

Since the beginning of the full-scale Russian war on Ukraine on 24 February 2022, energy infrastructure is being constantly targeted. According to the Second Ukrainian Energy Sector evaluation and damage assessment (as of September 24, 2022), electricity generation in 2022 will be 25% less than the "pre-war" forecast due to Russian military aggression. Three main challenges arose against this background. First, how to keep the lights on and balance the electricity system in a state of war? Second, what to do with the extensive electricity supply amid a drop in demand due to the interruption of big industries and the immigration of more than 6 million people abroad for safety reasons? Third, how to provide swift repair to strategic energy infrastructure and restore electricity flow after the infrastructure shelling?

All these significant challenges would not be possible to address without strong political support, prior technical preparedness, and robust crisis management of the main counterparties from the Ukrainian and EU sides. On the Ukrainian side, the rapid state reaction by submitting request for an urgent synchronisation and "the exceptional efforts of Ukrenergo to operate and maintain the power system" initiated the EU response.

At the highest EU political level, all the institutions: the European Commission, the Member States and Regulatory Authorities, were unanimous in their decision to synchronise Ukraine with the European electricity grid. In its turn, The European Union Agency for the Cooperation of Energy Regulators (ACER), the Council of European Energy Regulators (CEER), the European Network of Transmission System Operators for Electricity (ENTSO-E), and the Energy Community Secretariat were ready to provide all the technical support to materialise what politicians agreed on a paper.

Philipp C. Böttcher, Leonardo Rydin Gorjão, Christian Beck, Richard Jumar, Heiko Maass, Veit Hagenmeyer, Dirk Witthaut, and Benjamin Schäfer, "Initial analysis of the impact of the Ukrainian power grid synchronization with Continental Europe", Physics and Society, 15 April 2022, p. 5, https://arxiv.org/pdf/2204.07508.pdf



POLITICAL SUPPORT

Ukraine-EU cooperation in the energy sector was established long before the power systems synchronisation on 16 March 2022. The first "full integration" of the EU and Ukraine's energy markets was stated as a goal in the Memorandum of Understanding signed in 2005 and prolonged in 2016. The implementation level of harmonisation with the European acquis Communautaire is streamlined and monitored by the Energy Community Secretariat, to which Ukraine became one of the Contracting Parties in 2011.

The 24th of February gave a new spin to Ukraine-EU energy relations. In response to Russia's war of aggression against Ukraine, the European Union, led by the French Presidency of the Council, committed to ensuring continuous and uninterrupted electricity and gas flows to Ukraine and concluded that synchronisation of Ukrainian and Moldovan electricity grids with the EU's grids shows that "our futures are now interconnected".⁴ As a result, ENTSO-E and ACER were tasked to conduct all the necessary preparation for Ukraine's power system connection.

When ENTSO-E concluded the successful synchronisation, the Commissioner for Energy Kadri Simsonby confirmed that "ensuring the reverse flows of gas to the country and the delivery of energy supplies that are badly needed" will stay as the top priority for Ukraine-EU energy cooperation during the wartime.

Though at a glance, it may seem that the synchronisation of the two power systems benefits mainly Ukraine, there is more to that if we look at this event in the bigger context. Connecting Ukraine to the continental European grid is mutually beneficial for both parties. By 2050, electricity demand in the European Union is expected to rise up to 40%. Amid achieving the renewables target in line with the European Green Deal commitment, the EU strives to include neighbouring countries to expand green energy capacity.

European Council conclusions on the Russian military aggression against Ukraine, 24 March 2022, https://www.consilium.europa.eu/en/press/press-releases/2022/03/25/european-council-conclusions-on-the-russian-military-aggression-against-ukraine-24-march-2022/

Statement by Commissioner for Energy Kadri Simson on Synchronisation of the Continental European Electricity Grid with Ukraine and Moldova, 16 March 2022, https://ec.europa.eu/commission/presscorner/detail/en/statement_22_1789

Lukas Feldhaus, Kirsten Westphal and Georg Zachmann, "Connecting Ukraine to Europe's Electricity Grid: Technical Details and Hard Geopolitics", *Stiftung Wissenschaft und Politic*, Nº 57, November 2021, p. 1, https://www.swp-berlin.org/10.18449/2021C57/

Aura Sabadus, "Ukraine prepares for launch of ENTSO-E commercial electricity flows", ICIS, 9 June 2022, https://www.icis.com/explore/resources/ news/2022/06/09/10773192/ukraine-prepares-for-launch-of-entso-e-commercial-electricity-flows/



Considering that some forms of renewable energy, such as onshore wind, are not politically acceptable for all customers in the EU, exporting electricity from outside of the EU is an essential part of meeting the target.⁶ Against this background, Ukraine, with its immense potential to expand green energy production, legitimately seems a priority partner. Moreover, calculations showed that around 2GW worth of Ukrainian electricity exports could save around 5bcm in Russian natural gas imports annually for the EU.⁷

Moreover, as Alberto Pototschnig, Deputy Director of the Florence School of Regulation Energy, emphasised, "the wider the synchronous system, the more resources contribute to keeping the frequency stable, the easier this is".8 It means that in the mid and long-term perspective, when Ukraine wins and there is no more direct danger to the power system stability, the extension of the continental European electricity grid to Ukraine and Moldova will also increase the grid's resilience and stability.

To sum up, the political will from both the Ukrainian and the EU sides was there, so the policy and political reasoning behind the logic of greenlighting the synchronisation of the Continental European Electricity Grid with Ukraine and Moldova. Even without the Russian full-scale invasion on 24 February, the Ukraine and Moldova power system synchronisation with ENTSO-E would happen, though Russian aggression had accelerated the pace of the implementation of the previous agreements.

TECHNICAL FEASIBILITY

Ukraine and its transmission system operator Ukrenergo signed the agreement with the European Network of Transmission System Operators for Electricity (ENTSO-E) in 2017. Unlike previously mentioned high-level documents, the agreement stipulates technical preconditions, including the Catalogue of Measures, which the planned synchronisation must fulfil in 2023.

Since 2017, the Ukrainian Government has continuously invested in the technical capacity of Ukraine's electricity grid to tick the Catalogue boxes.

Robert Schuman Centre for Advanced Studies, "Ukraine and Moldova in the Continental European Electricity Grid", 17 March 2022, https://www.eui.eu/news-hub?id=ukraine-and-moldova-in-the-continental-european-electricity-grid

Ukrenergo, "Integration into ENTSO-E. Key results over two years", 30 May 2019, https://www.slideshare.net/Ukrenergo/integration-into-entsoe-key-results-over-two-years



A total of EUR 357 mln has been invested into grid development, generation readiness to ensure reserves and automatic voltage control, development of communication channels for dispatching operations, and additional studies on the static and dynamic stability Implementation of the Operation Handbook ENTSO-E.9

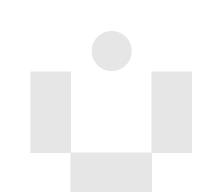
"There were many things already in place. Without previous work done, it [synchronisation] would not be possible. Plus, infrastructure was already there," said the key ENTSO-E managers of Ukraine's synchronisation with the European grid. Moreover, since 2003 there was already an existing connection of the Burshtyn Island power plant with ENTSO-E, which has given Ukraine some practical experience in synchronising with another grid.

Before the synchronization on 16 March, the previous studies conducted by the ENTSO-E TSO Consortium concluded the readiness and the adoption of risk mitigation measures by Ukraine. Even though there were still conditions that had to be fulfilled, the synchronisation was possible without any reinforcements or additional infrastructure.¹¹

From the technical point of view, before synchronisation with the continental European grid, Ukraine's electricity grid must have run a few tests of being operated in island mode, meaning preserving the same frequency of 50 Herts in the grid and balancing the system without support from the neighbouring countries: in this case – Russian and Belarus.

On 27 February 2022, the last day of the isolated mode test, the Ukrainian TSO Ukrenergo sent an urgent request to Continental Europe TSOs for an emergency synchronisation of the Ukrainian power system, including the Burshtyn island with the Continental Europe power system. The next day, the Moldavian TSO Moldelectrica also submitted a request. Moldova is not a controlled area; therefore, it highly depends on Ukraine in terms of synchronisation.

ENTSO-E had to assess technical conditions, such as Protection and Dynamic Stability, Operations and Markets, Legal and Regulatory and Information Technology, including Cybersecurity. On 11 March, ENTSO-E concluded that the conditions for an emergency synchronisation were met, following the actual synchronisation on 16 March.¹²



Following the major milestone of synchronisation, on 26 April 2022, ENTSO-E welcomed Ukrenergo as an observer member. Along with the new status in the ENTSO-E, Ukrenergo went even further and requested the start of commercial electricity exchanges with the Ukraine/Moldova power system. It started as planned on 30 June with the first power flow at the level of 100 MW through the interconnection between Ukraine and Romania with the perspective to send electricity to neighbouring Slovakia, Hungary, and Poland at a later stage¹³ As of 5 September 2022, the trade capacity with Ukraine/Moldova increased to 300 MW during the day, keeping the trade capacity at 250 MW during the night.¹⁴

In order to conduct the emergency synchronisation, the Catalogue of Measures was divided into the first and the second-priority pack of requirements. The emergency synchronisation allows this step-by-step approach though, ensuring additional mitigation measures to limit the operational risks. The first priority requirements were essential to carry on as soon as possible. The IT data exchange interconnection was the most difficult one in this pack. It usually takes six months to establish the interconnection. However, in the midst of the emergency situation, the ENTSO-E installed an IT connection between the control centre of Ukraine and the one of ENTSO-E in one week, which was unprecedently quick, as the ENTSO-E Task Force workstream IT/ Communications leader said.

Ultimately, it is a combination of past dependency in the Catalogue of Measures implementation, accelerated though a step-by-step approach and prioritisation of first-priority measures – that provided a solid technical ground for Ukraine's synchronisation with the European power grid.

ENTSO-E, "Continental Europe successful synchronisation with Ukraine and Moldova power systems", 16 March 2022, https://www.entsoe.eu/news/2022/03/16/continental-europe-successful-synchronisation-with-ukraine-and-moldova-power-systems/

Ukrenergo, "IPS of Ukraine can be synchronised with the ENTSO-E power system – conclusion of the ENTSO-E TSO Consortium studies", 30

December 2021, https://ua.energy/media-2/ips-of-ukraine-can-be-synchronised-with-the-entso-e-power-system-conclusion-of-the-entso-e-tso-consortium-studies/

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ENTSO-E, "Commercial exchanges of electricity with Ukraine/Moldova to start on 30 June", 28 June 2022, https://www.entsoe.eu/
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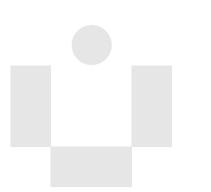
CRISIS MANAGEMENT

According to the ENTSO-E staff, Ukrainian TSO Ukrenergo wanted to speed up the implementation of the synchronisation agreement back at the end of 2021, reacting to the ever-growing Russian escalation and threat of using power connection with Russia to blackmail Ukraine. As mentioned by one of the ENTSO-E Ukraine's synchronisation Task Force, "isolated mode was a moment of fragility because the balance of the electricity grid is more difficult in isolated mode, so it was not surprising that Russia decided to invade Ukraine exactly during the test".

The synchronisation of Ukraine's electricity grid to the European one was conducted in the crisis management mode requiring intensive involvement of all TSOs. The 42 members of the ENTSO-E had to be in favour of synchronisation for it to materialise. As immediate neighbours, Slovakia, Hungary, Poland and Romania had a particular role to play because they were the first to feel the effect of Ukraine's synchronisation. Hungary was the least enthusiastic about this work but the most natural team leader because four out of seven interconnection lines from Ukraine go through Hungary. Though other countries' TSOs' representatives were more willing to take the burden, the decision was still made in favour of the most logical composition of management.

It implied extra working hours for the ENTSO-E colleagues, including weekends. At the same time, Ukrenergo had to work under extreme circumstances meaning not sleeping amid Russian missile bombardment though still managing to turn up for daily online meetings. ENTSO-E and Ukrenergo conducted 24/7 monitoring of the situation to swiftly respond with appropriate measures depending on the fast-changing situation in Ukraine.

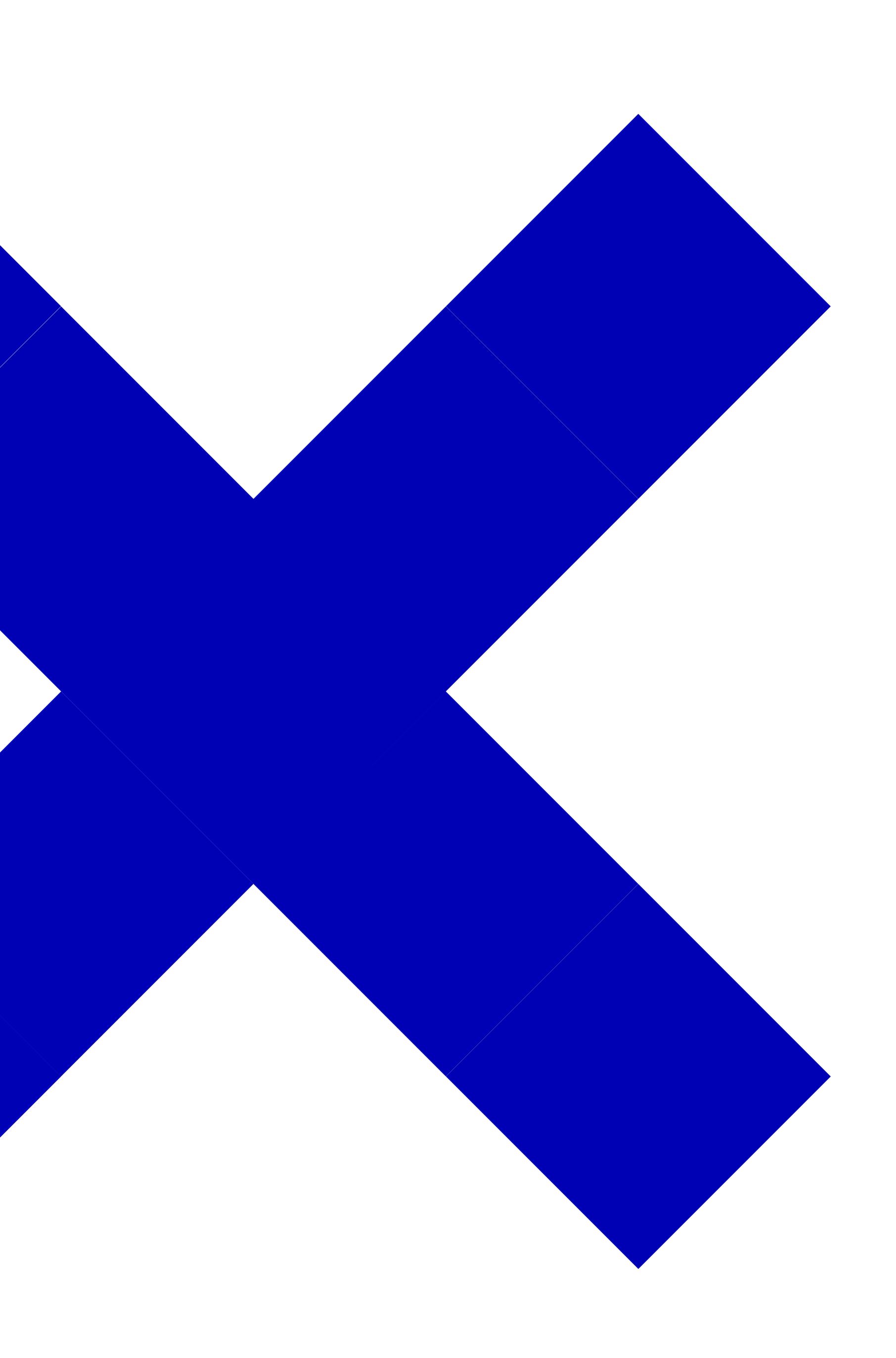
As was mentioned more than once by all the interviewed parties, in the TSOs' business, professionals are used to working in emergencies. People usually work shoulder to shoulder; they know each other and trust each other. "This is like a family", as one of the ENTSO TF team leaders described it; "Even though a qualified majority must take decisions, we tend to decide by unanimity".



"We followed straightforward rules. Every day, we had an online meeting and accepted all the TSOs' representatives who wanted to participate. Normally, the attendance rate for a call is about 15 participants, but for Ukraine's cause, the number sometimes reaches 50 people on a call. Everyone genuinely wanted to help," explained the team leader. ENTSO-E also had previous experience working with at least 4 Ukrenergo employees who already had a high professional reputation among the dedicated TF.

The TF's members particularly pointed out the exceptionally high professionalism of Ukrenergo's electrical engineers. "I must admit I admire the level of competence in Ukrenergo. Apart from technical and managerial skills, I also think you [Ukraine] managed to make it because you had nothing to lose. You either do everything within your power and succeed or...", as shared by one of the interviewees.

To conclude, strong professional ties, a moral imperative, an acknowledged sense of urgency, many hours of work outside regular hours, and extra effort made Ukraine's synchronisation with the European continental electricity grid possible.



OUTCOMES

Due to the unprecedented effort of Ukrenergo and ENTSO-E, Ukraine and Moldova were synchronised with the Continental European grid in two weeks instead of 1 year, despite Russian full-scale conventional war of aggression unfolding in the background.

Political will from both the Ukrainian and European Union sides, as well as technical preparedness and well-coordinated crisis management, resulted in the decoupling of Belarus and Russia's power system and opening the perspectives of becoming a part of the European electricity market.

Ukraine set a trade record in the first two weeks of September 2022, exporting \$131 million worth of electricity. According to Ukrenergo, the total cost of access to interstate power grids in the direction of Slovakia and Romania, sold at Ukrenergo auctions from June 30 to October 9, 2022, amounted to more than 4.9 billion hryvnias. 16

Though the implementation of the European Electricity Network Codes and Guidelines has to be postponed due to the more urgent needs of the Ukrainian power system, such as balancing and stable supply for the households, the profound reform of the electricity market is inevitable in the mid and long-term perspective.

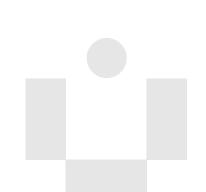
On 10 October 2022, Russia launched 84 cruise missiles and 24 drones against peaceful cities in Ukraine. TPPs and CHPPs were shelled in central, western, eastern, and southern parts of Ukraine. As an immediate result, more than 300 households in Kyiv, Lviv, Sumy, Ternopil and Khmelnytskyi regions stayed without power. To stabilize the system and meet the domestic demand the Ministry of Energy of Ukraine announced a temporary termination of the electricity trade.¹⁷

International Energy Charter, "Ukrainian energy sector evaluation and damage assessment – II (as of September 24, 2022). Cooperation for Restoring the Ukrainian Energy Infrastructure project, Task Force", P. 8, https://www.energycharter.org/fileadmin/DocumentsMedia/
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The Official website of the Ministry of Energy of Ukraine, "Ukraine stops exporting electricity due to Russian missile attacks on energy facilities", 10 October 2022, https://www.mev.gov.ua/novyna/ukrayina-prypynyaye-eksport-elektroenerhiyi-cherez-rosiyski-raketni-obstrily-enerhetychnykh



CONCLUSIONS

In 2005, Ukraine and the EU first committed to couple their energy systems later confirmed in various high-level political agreements and reinforced through the status of the Contracting Party in the Energy Community and technical agreement with ENTSO-E about physical synchronization of Ukraine, Moldova and the European continental power grids.

The actual synchronisation was scheduled in 2023, though due to the Russian full-scale war of aggression on Ukraine, it was conducted one year earlier in 2 weeks thanks to the enormous effort of ENTSO-E and Ukrenergo, with the unanimous political commitment and support of the EU.

From mid-March until mid-October, Ukraine managed to agree on the gradual rise of commercial electricity trade with neighbouring EU countries. Before a mass shelling on 10 October, Ukraine reached a commercial exchange at the level of about 500 MW per hour creating additional inflow to the state budget and simultaneously contributing to the available capacity at the European electricity market even though limited to the neighbouring EU countries.

Exposing the Ukrainian overregulated ill-functioned electricity market to the European electricity market rules will inevitably lead to an accelerated transition to competitive pricing, and phase out the fossil fuels subsidies in the mid-and long-term perspective. As a side effect, the Russian invasion of Ukraine and the following Ukraine and Moldova emergency synchronisation will lead to an accelerated synchronization of the Baltic power grids to the Continental European one.

Meanwhile, the risks for the smooth operations of the Ukrainian power grid remain high. As of September 24, 2022, Russia occupied or damaged about 40% of the country's installed power capacity though the cost of recovery is raising almost every day due to the ongoing shelling by Russian troops. Following the massive missile attack on 10 October, in most of the Ukrainian regions, the rotating system of power supply was introduced though the situation is changing on the daily basis thanks to the heroic effort of electricity engineers on the ground.

The 2022-2023 heating season will further test the resilience of the Ukrainian energy system and European commitment to support the people of Ukraine in the darkest days of Ukrainian history.



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