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NUCLEAR FACILITIES AS MILITARY TARGETS – THE ZAPORIZHZHIA CASE

For the first time in history, a nuclear power plant became a military objective during a war. This also highlights the lack of a ratified global agreement or treaty on non-aggression to nuclear facilities, or of another type, whose destruction entails a great impact on the population. On the other hand, the standards and guides for nuclear safety and protection of the International Atomic Energy Agency (IAEA), without a mandate for military contexts, cannot currently be applied to nuclear facilities in armed conflicts.

Nor can it be admissible that the gradual loss of safety levels and margins, which the Zaporizhzhia nuclear power plant has been suffering for a long time, is brewing a potential slow-motion disaster to the frustration of the international community. Certainly, the insecure electricity supply necessary to maintain its safety systems, the difficulties in maintaining its coolant inventory as a result of the destruction of the Kakhovka dam, the dispute over the plant with detonations on the war front and with mines placed between the site's internal and external perimeter barriers, as well as the current insufficiency staff to ensure adequate maintenance of all the equipment, are all elements that make the situation of the Zaporizhzhia plant unacceptable in the medium term.

Global treaty of non-aggression against nuclear facilities

Military operations have already been carried out in the past on nuclear facilities such as at the Iraqi Osirak (French Osiris-class) nuclear research reactor destroyed in 1981 by Israeli F-16s, as well as at the two reactors under construction at Iran's Bushehr nuclear power plant (Siemens-KWU) bombed in 1987 by Iraqi fighters during the Iraq-Iran war. There were also military actions in 1991 at the site of the Slovenian Krško (Westinghouse) nuclear power plant.

While previous actions were somewhat ad hoc, the Zaporizhzhia nuclear power plant continues to be contested between the parties as a war target, a new and unprecedented situation for which the international community is unprepared. The first military actions on nuclear facilities in this war also affected the exclusion zone of the damaged Chornobyl nuclear power plant and the nuclear research centres KINR in Kyiv and NSC-KIPT in Kharkiv. Although there has been no external radiological impact to date, it is imperative to prevent Zaporizhzhia and any nuclear facilities from becoming military targets.

In this regard, there are various related legal frameworks. The 1949 Geneva Conventions were extended by several additional protocols. Additional Protocol I of 1977 refers to international

armed conflicts and in its article 56 to certain restrictions on the protection of facilities. However, among other countries, the Russian Federation withdrew its 1989 ratification of this protocol in 2019 and the USA never ratified it, explicitly rejecting Article 56 in its Law of War Manual of the US Department of Defence. Nor does the 1979 IAEA Convention on the Physical Protection of Nuclear Material and Nuclear Facilities, amended in 2005, which criminalises illicit trafficking and sabotage of nuclear materials or nuclear facilities but does not cover military attacks on such facilities.

These rules are ambiguous and confer a certain legal vacuum, so that attacking a nuclear facility may not be illegal. There is therefore an urgent need for a global convention or treaty on non-aggression against nuclear facilities to prevent such facilities (as well as dams, chemical facilities, etc.) from being used as military targets. Even if in the madness of a war some country did not abide by such a norm, the very existence of international rules should prevent the normalisation of possible future aggressions during armed conflicts, would delegitimise any warlike action on such facilities and would deny the possibility of justifying them.

The annual IAEA General Conference in 2019 already recognised the need to prohibit armed attacks on nuclear facilities. More recently, there have been attempts to move in this direction, such as at the Nuclear Non-Proliferation Treaty Review Conference of August 2022 also aiming to prohibit nuclear facilities from becoming military targets, including in scenarios with change of control of disputed territories. Furthermore, the resolution voted on 29 September 2022 at the IAEA General Conference concerning the risk of fighting in Ukrainian power plants including Zaporizhzhia, was rejected by Russia as Zaporizhzhia is already located in a Russian province.

If conventional nuclear fission power is to continue to produce electricity for the world, the international community must ensure that its facilities are kept strictly out of any armed conflict. Immediate action by the international community is needed to prevent a possible catastrophe during this war and to reduce the current risk of a nuclear accident at Ukrainian nuclear power plants. It is worth mentioning that due to the shelling of some power substations, the frequency of the punished and unstable Ukrainian power grid dropped excessively in November 2022 and all four Ukrainian power plants simultaneously lost external power supply and had to rely exclusively on their emergency diesel generators, for which spare parts have been preventively supplied.

However, there are also very positive agreements. India and Pakistan signed a 'Nuclear Non-Aggression Agreement' in 1988 that basically prohibits "undertaking, encouraging or participating, directly or indirectly, in any action to destroy or cause damage to nuclear installations of the two countries". Another example is the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) created in 1991 as the only binational organisation sharing nuclear safeguards. These examples of bilateral agreements encourage a similar pattern at the global level. A reactivation of the Nuclear Security Summit, which has not been active since 2016, could be also an influential element to seek consensus and begin to reverse the current situation.

Specific risks at the Zaporizhzhia nuclear power plant

The Zaporizhzhia nuclear power plant was militarily intervened on 4 March 2022 by Russia that decreed its ownership 5 October 2022. Its six Russian-designed VVER-1100 reactors produced 27% of Ukrainian electricity before the war and its location is crucial for the electricity supply of Crimea and the Donbas region. The plant is still operated by Ukrainian staff together with new Russian operators of Rosenergoatom and controlled by the Russian state-owned Rosatom.

With the takeover of the plant, some 100 Ukrainian operators had already signed in October 2022 - against the indications of Ukraine's Energoatom - contracts with Russia's state-owned Rosatom to keep their jobs, while Russian operator Rosenergoatom implemented a new operational structure, also with new Russian staff. Many plant employees and their families left the town of Energodar, which at times was short of water and electricity. In April 2023, a reduction of maintenance staff was estimated at 75%, with approximately 3,000 Ukrainians and 200 Russians working at the plant in July 2023. In this regard, Russia continues to announce the recruitment of personnel and claims to have enough specialists to operate all equipment and safely carry out maintenance work at the plant.

Beyond the anguish and stress to which the operators are subjected by the war context and the mentioned restrictions, a clear example of their discomfort is the uncertainty about who is responsible for the safety of the plant and about the chain of command in case of radiological emergencies. At the beginning of 2023, Russia intended to activate the Z-5 reactor (without announcing the type of operation and power level planned) to supply areas under its control, while the Ukrainian regulator SNRIU on 10 February disallowed the restart of the operation until Ukraine regained control of it, later decreeing the return of the Z-5 reactor from hot shutdown to cold shutdown. The Z-4 reactor was brought to hot shutdown condition on 25 July replacing the Z-5 reactor brought to cold shutdown on 28 July. But due to problems at Z-4 reactor, it was brought on 10 August again to cold shutdown and Z-6 was prepared to be brought to hot shutdown to produce steam for various technical purposes. Meanwhile, the referred Ukrainian regulator SNRIU continues to issue regulatory orders for all six reactors to be in cold shutdown. Despite the professionalism of the operators, all these uncertainties have a negative impact on the safety culture and hinder maintenance work to ensure the proper functioning of the various plant equipment.



Six reactors of the Zaporizhzhia nuclear power plant (Ralf1969, CC BY-SA 3.0, via Wikimedia Commons)

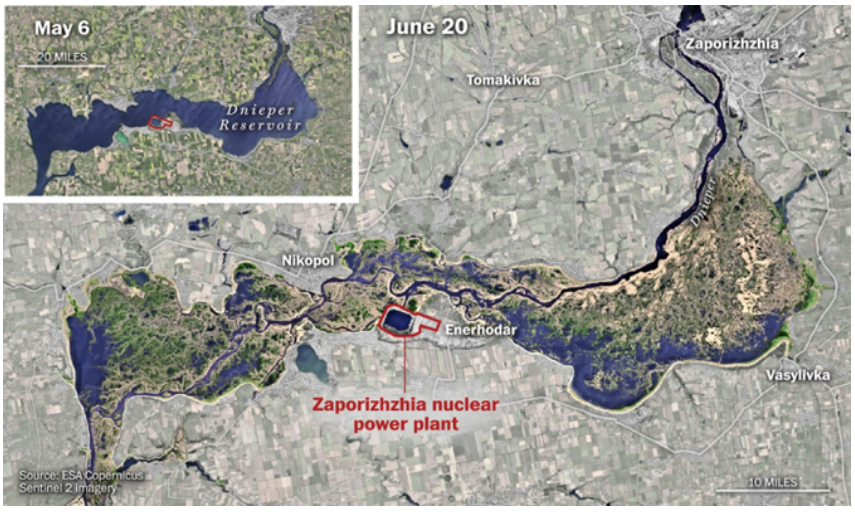
After the outbreak of the war, the IAEA established seven indispensable pillars of nuclear safety and security to assess risks in wartime contexts. They refer basically to physical integrity of all facilities; full functioning of all safety and security systems; working conditions and ability of operators to perform their duties and make decisions without undue pressure; ensuring external power supply; ensuring logistical supply and transportation to the site; effective radiological monitoring and emergency preparedness; and reliable communication with the nuclear regulator. The UN Security Council agreed to send IAEA inspectors to Zaporizhzhia on 11 August 2022. With its first support and assistance mission to the plant - with its six reactors shut down - on 1 September, the IAEA concluded that all these nuclear safety and security pillars were to a greater or lesser extent compromised and recommended specific actions, as well as the establishment of a safety protection zone without military equipment around the plant, already occupied by Russian troops. The IAEA established shifts of nuclear safety inspectors since that 1 September 2022 in Zaporizhzhia (arriving the tenth shift last 2 August) and since January 2023 in the other four Ukrainian nuclear power plants, as well as a mission to support and assist the safety and protection of radioactive sources used for medicine and industry, located in various institutions in the country.

In view of the impossibility of creating the required safety protection zone and the continued fighting in the area, the UN Security Council endorsed on 30 May 2023 the five concrete principles essential for averting a catastrophic incident at the Zaporizhzhia plant, established by the IAEA: there can be no attacks of any kind from or against the plant, in particular directed at reactors, irradiated fuel storage, critical infrastructure or personnel; the plant cannot be used as storage or seating for heavy weaponry or military personnel that could be used for an attack from the plant; the external power supply cannot be placed at risk and must be secured at all times; all structures, systems and components essential to safety must be protected from attack or sabotage; and no action that undermines these principles must be taken.

Indeed, the fragility of the Ukrainian electricity grid and infrastructure means that the safety in Zaporizhzhia remains dependent on external power supply. The last incident regards the only 750 kV line of the four pre-war lines that had been operational since August 2022, which was disconnected from the grid on 4 & 22 July and 10 August 2023, making the plant's safety functions dependent during those three days only on one of the six other 330 kV external support lines that had not been operational since 1 March 2023 and that could fortunately be recovered just on 1 July. That is, only one of the ten high voltage lines installed was operational. In the event of a total external power outage, the plant must be operated with emergency diesel generators as a last resort, which occurred in October 2022 for the first time in the plant's 37-year history, and which meanwhile has already occurred seven times (!). These diesel-powered generators have increased their reserves from ten days to around 23 days.

In addition, the Kakhovka dam with a reservoir of 2155 km² was destroyed on 6 June 2023, with a devastating human, agricultural and ecological impact on the region and even on the Black Sea. The destruction of the dam also represented a significant decrease in the water available in the Kakhovka reservoir used to cool the plant 128 km upstream. There was no imminent loss of coolant supply, but with the reservoir level lowered below 11 m on 20 June it is no longer possible

to refill the cooling pond next to the power plant from the reservoir. While the reservoir was being drained to that level, it was still possible to completely fill the reservoir till 16.63 m, being now that reservoir mainly fed from the discharge of the neighbouring DRES thermal power plant in Energodar. The available water supply remains relatively stable. Although it is estimated that this scheme can cool the plant for a few months, further measures are being considered to ensure sufficient cooling in the long term.



Kakhovka reservoir drained on 20 June after the destruction of its dam on 6 June 2023 (Copernicus Sentinel data 2023)

The safe cooling of nuclear fuels, which remains the biggest challenge, depends on the power supply and now also on the cooling pond (by design higher than the reservoir) whose isolation gates have been reinforced and whose structural integrity is vital to prevent coolant leakage or collapse. However, there are alternative means and emergency procedures that were developed after the Fukushima accident in 2011 to keep this pond in a condition to cool the plant. Overseen by the European Nuclear Safety Regulators Group (ENSREG), stress tests were performed in European facilities and Ukraine developed a national action plan in 2013, updated with a final review in 2020, to strengthen safety systems against extreme events, including the breach of the Kakhovka dam. Consequently, certain emergency procedures were expanded with new equipment and infrastructure available, such as mobile vehicles and pumping boats, submersible pumps, and the opening of wells within the perimeter of the site, to ensure long-term cooling of the plant without power supply. Also, hydrogen recombiners and filtered vents were installed for accident scenarios in the reactor containment as result of the referred stress tests.

In addition, there are two further elements that increase the risk of an accident. On the one hand, new detonations, and mine explosions, such as those that have occurred repeatedly, and even possible sabotage or terrorist actions. All of this could render the plant unusable by destroying conventional non-nuclear equipment, such as some placed in turbine halls and electrical alternators. But such explosions could also affect installations with a potential radioactive impact, such as fuel and radioactive waste storage facilities, electrical equipment supplying safety systems or even the cooling pond or the discharge channel of the DRES thermal power plant,

which following the destruction of the Kakhovka dam is now vital to ensure the cooling of the plant's fuels. On the other hand, the difficulties to fully carry out the in-service inspection and maintenance programmes due to insufficient staff, lack of external contractors and specific spare parts is another important risk factor.

The situation at Zaporizhzhia with such significant reductions in safety levels and margins (so-called loss of safety depth) is unsustainable in the medium term. Zaporizhzhia needs to be protected since there is a real and permanent fear of a nuclear accident. Although in the current state of the facilities, a Chornobyl-type accident cannot occur for physical and technological reasons, if certain essential systems were to be affected, there would be the risk of not being able to ensure safe cooling of the residual heat from the reactors and the irradiated fuel. In such a case, fuel meltdowns could occur with release of radioactive products, i.e., level 4 or higher on the INES nuclear event scale (reactor damage and radioactive release). The phenomenology of such a potential accident would be like a Fukushima-type scenario (level 7 on the INES scale), but with less impact since the residual heat of the fuels to be cooled at Zaporizhzhia is quite low as the reactors have been shut down since 11 November 2022. However, a complete and definitive lack of coolant would cause a fuel meltdown accident with a release of radioactive products which, depending on the magnitude of the release, could have a transboundary and indiscriminate impact affecting several countries. The world's reaction would have to be seen, but such a scenario would alter the course of the conflict, leading to possible outside humanitarian interventions and escalating the dimension of the war.

Global challenges for nuclear safety and security standards

The war in Ukraine represents a major challenge for global nuclear safety and security given that beyond possible legal agreements prohibiting and trying to prevent attacks on nuclear facilities, there must also be guidelines and rules to manage the safety and security of nuclear facilities in war scenarios. The 1991 technical assessments at the Slovenian Krško power plant addressed various technical aspects related to subcriticality, fuel cooling, containment integrity and radiological inventory. But this work was not used, as mentioned above, to develop IAEA guidance for war contexts, since in principle the IAEA's mandate does not include dealing with armed conflicts and military facilities.

In the same way that the Chornobyl catastrophe accelerated the further development of IAEA nuclear safety standards, and the Fukushima accident triggered the various nuclear safety action plans for extreme events by the IAEA, Euratom and others, this war should legitimise the IAEA to monitor and support nuclear facilities in armed conflicts. To this end, the mandate of the IAEA, which depends on the United Nations, should possibly be rethought and adapted, so that the IAEA Commission and Safety Standards Committees could fully develop the safety standards and guidelines for wartime environments.

In this regard, the extent to which current nuclear safety and security standards can be applied to armed conflict scenarios is already being analysed. In July 2022, the IAEA launched a working group to analyse the applicability of its current safety and security standards and guidelines in

armed conflicts, based on the knowledge and experience that continues to be acquired in Zaporizhzhia. Consequently, the above-mentioned seven pillars of nuclear safety and security together with the five principles of protection, all established by the IAEA for Zaporizhzhia, are also basic elements for the development of these specific standards and guidelines. Following the eight meetings held by that working group, the meeting of the IAEA Safety Standards Committee on 23-26 May 2023 addressed the applicability of its standards to war scenarios. It was agreed to publish a technical document to guide the international community and to be updated as events unfold in Zaporizhzhia. Called TECDOC in the IAEA vocabulary, it will concern the practical applicability of current standards, shortcomings or challenges in their application and lessons learned. In addition to securing safe areas without military equipment at nuclear facilities and preventing their use as troop protection, consideration should also be given to placing them under international control in war contexts. It should also be possible to unambiguously identify responsibilities for nuclear safety, physical protection and radiological emergency preparedness, especially in cases of sequestered management of facilities, as is currently the case in Zaporizhzhia.

However, given that such an exercise has broad dimensions and long-term implications, it requires much analysis and caution before firm conclusions can be drawn on the applicability of some of the current IAEA standards. It is therefore premature to validate existing or new IAEA standards and guidance for war scenarios while the war continues. However, the current work within the IAEA framework would have a multiplier effect on those countries having own regulatory agencies that could also develop their national standards.

It is worth noting that, as an autonomous UN agency created in 1957, the IAEA is the only international body coordinating technical assistance to Ukrainian nuclear facilities. Following IAEA inspections of non-existent weapons of mass destruction in Iraq, the Nobel Peace Prize was awarded in 2005 to the IAEA for "its continued work for a safer and more peaceful world". Its nuclear proliferation safeguards programmes are widely recognised, including its technical support for Iran's JCPOA nuclear agreement with the European Union, the United States, Russia, China, France, the United Kingdom and Germany, as well as its monitoring of North Korea's nuclear weapons development.

Although limited, the IAEA inspectors' presence and action on site helps Zaporizhzhia and brings clarity by informing the world of its situation, especially at a time of unverified allegations. IAEA Director General Rafael Grossi presented the Zaporizhzhia scenario on 5 June 2023 to the IAEA Board of Governors, had to report just one day later the new context after the destruction of the Kakhovka dam, and visited Zaporizhzhia for the third time on 15 June with a new reinforced shift of inspectors. Grossi continues to negotiate and seek consensus at the highest level between the parties with his latest meetings in Kyiv on 13 June and in Kaliningrad on 23 June. The IAEA is also seeking greater engagement and support from the international community.

In theory, nobody wants a nuclear accident, but for the first time a nuclear power plant is being disputed as an objective on a war front, with both contenders accusing each other of misinformation and preparing sabotage or terrorist actions at the power plant, which would

break some of the protection principles agreed a few weeks ago in the Security Council. With various safety margins decreasing, Zaporizhzhia is in a kind of grace period that is not infinite. A possible slow-motion disaster has been brewing for a long time and the world must be able to act now before it happens.