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INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

INFORMATION NOTE

Description of the Zaporizhzhya nuclear power plant and its environment

Date: 06/09/2022

The Zaporizhzya nuclear power plant, operated by the Ukrainian staff of Energoatom, has been under the control of Russian forces since March 4, 2022. It has been recently the subject of several bombings, causing great concern about the possible consequences:

- 5 August: bombing of a 330 kV transformer which led to the automatic shutdown of reactor no. 3 and the starting of its emergency generators;
- August 5: bombing and damage to a nitrogen production station;
- August 6: bombing near the spent fuel dry storage site;
- August 11: bombings damaging fire-fighting equipment, a non-radioactive effluent pumping station and radioactivity measurement sensors;
- August 22: bombing near the thermal power plant causing damage to the electrical interconnection line with the nuclear power plant;
- August 23: bombing between the nuclear power plant and the neighboring town of Energodar, resulting in fires in the vegetation near the plant;
- August 25: bombing to the north of the thermal power plant next to the nuclear power plant, resulting in vegetation fires and a temporary disconnection of the nuclear power plant from the electrical grid; emergency diesels would have started;
- August 25: bombing of an access gallery of reactor no. 2 (link with operating building no. 1), damaging water pipes and electrical links;
- August 28: bombing of the exploitation building n°1 leading to a perforation of the roof and damages in the present equipment;
- September 1st: bombing of the site leading to the cutting of a 750 kV power line, the shutdown of reactor no. 5 and the starting of the emergency diesels of reactor no. 2;
- September 5: bombing near the thermal power plant which led the operator to cut the last power line connecting the plant to the Ukrainian power grid.

To date, none of these bombings has resulted in radioactive releases at the site. No increase in radioactivity has been detected by the environmental monitoring networks located near the plant. The site teams intervened each time to restore the situation as far as possible.

In order to facilitate the understanding of the consequences of the recurrent events occurring at the Zaporizhzya nuclear power plant site, this note resituates the plant in its environment, describes the site and recalls the main issues related to its safety in the current context.

The site of Zaporizhzya and its environment (figure 1)

The site of Zaporizhzya is located on the left bank of the Dnieper at the level of the Kakhovka reservoir, limited downstream by the Kakhovka dam and hydroelectric power station and upstream by the Dnipro dam and hydroelectric power station. The bridges allowing to cross the Dnieper upstream or downstream are more than two hours away from the power plant.

Figure 1 shows the electrical network in the area of the Zaporizhzya power plant. Four 750 kV and two 330 kV power lines connect the plant to the power grid.

The plant systems are powered by the 750 kV grid during operation. In case of failure of the 750 kV grid (Figure 3), reactors 1 and 2 can be supplied by a 150 kV line via the thermal power station[1] and reactors 3, 4, 5 and 6 by two 330 kV lines via the same power station. Connections between the reactors allow mutual backup of the power supplies for their backup safety systems.

At the end of August, only a 750 kV line (to the north) and a 330 kV line appeared to be available. At the beginning of September, only the 330 kV line would be available. The situation appears to be very evolving.

Finally, Figure 1 shows the location of the environmental monitoring stations, whether they belong to the plant operator or the Ukrainian national monitoring network. The data from these networks are generally available in near real time either through the IAEA IRMIS network or the European Commission (EURDEP) network.

Facilities at the Zaporizhzhya power plant site (Figure 2)

Figure 2 shows a detailed site plan of the Zaporizhzhya NPP. The site consists of six Russian-designed VVER 1000 reactors. Each of the reactor cores is protected by a containment system that also houses the spent fuel pool. After a few years, the spent fuel is transferred from the spent fuel pool to containers stored outside in a dedicated area (dry storage).

The site also includes many facilities dedicated to the operation of the plant: chemical treatment of the water circuits, management and storage of radioactive effluents (special buildings), conditioning and storage of solid radioactive waste, training center, laboratories ....

Main issues in terms of safety

Loss of water intakes

[1] This thermal power plant is currently shut down.

To ensure the cooling of the installations, a retention basin has been built with a headrace canal and a discharge canal for the supply of the conventional part of the nuclear power plant. Each reactor has a water intake on the headrace canal.

In case of failure of the water intake (for example, if the water level in the retention basin was too low), the reactors would be shut down and the cooling of the nuclear reactor cores and spent fuel storage pools would be ensured by a circuit connected to a basin equipped with sprinkler systems (Figure 2). A make-up of water in this basin is necessary to compensate for water loss by evaporation.

Power plant loss

The power supply to the Zaporizhzya NPP is currently particularly weakened. In the case of a total loss of off-site power, one or more reactors in operation could continue generating power for all six Zaporizhzhya NPP reactors, subject to a successful "islanding transient"[2] . The reliability of this operation, which is not a common operating practice, is limited. Moreover, it is not a permanent solution.

Each reactor has three backup power generators (6.6 kV). One generator is sufficient to maintain the reactor in a safe state. Furthermore, two generators, protected against aggression and malicious acts (bunkerized), are also present on the site. The stocks of fuel for the generators could allow them to operate for seven to ten days, time limit after which the refueling becomes necessary.

However, the status of fuel stocks is not known.

Radiological issues in case of an accident

The Zaporizhzya nuclear power plant presents major radiological challenges in case of an accident.

- The cooling of the fuel in the reactor cores or in the spent fuel pools must be ensured on a continuous basis: a prolonged failure of the cooling (loss of water intakes and/or loss of electrical power) would lead to a fuel meltdown accident and radioactive releases to the environment; the extent of the releases would depend on the tightness of the containments and the availability of a means of heat removal inside the containments;
- The dry storage site for spent fuel (in containers) is vulnerable to bombing: the containers are made of robust steel and concrete structures, but their damage would lead to a dispersion of radioactive materials, with consequences outside of the facilities, the extent of which would depend on the damage suffered by the containers;
- Other parts of the installation containing radioactive materials are also vulnerable in the case of bombing (storage of solid waste, liquid or gaseous radioactive effluents); the effects would nevertheless be limited to the site itself.

In the last two cases, there would be an immediate radioactive release. In the first case, the release would be deferred, which would allow the population to be alerted for evacuation, sheltering or iodine pills intake.

[2] After the islanding transient, the power supply of a reactor is ensured directly by its main alternator and no longer by the external electrical grid.

In all cases, the environmental radioactivity measurement stations will allow the detection of radioactive releases.

Human, organizational and logistical issues

The plant has been occupied by Russian troops since early March. It seems that a strong constraint is exercised on the Energoatom Ukrainian staff who continues to operate the plant. This stress level of the staff, for about 6 months, strongly increases the human factor risk level likely to induce a nuclear incident or accident. As the Ukrainian safety authority inspectors are no longer able to carry out their mandate on site, it is not possible to know whether the operating rules, in particular periodic tests and maintenance operations, are correctly implemented. All kinds of equipment supply to operate the plant (consumables such as boron) or maintenance operations are for sure very disrupted.

In addition, due to limited communications, the technical crisis centers required in case of a nuclear accident are not fully operational. The logistical means that would be essential to manage accident situations are no longer guaranteed.

According to IRSN, the situation at the Zaporizhzya nuclear power plant and the teams in charge of its operation is currently very deteriorated: the IAEA mission could provide useful information on the state of the installations and operating conditions.

1. Note d'information de l'IRSN du 22 mars 2022 Information note from the IRSN of March 2022: "Provisions planned in the event of a total loss of external power supplies to the Zaporizhzhya power plant in Ukraine".
2. Note d'information de l'IRSN du 08 août 2022 Situation of the Zaporizhzhya nuclear power plant in Ukraine after the bombings of 5 and 6 August 2022".
3. Note d'information de l'IRSN du 12 août 2022 Situation of the Zaporizhzhya nuclear power plant in Ukraine after the bombings of August 11, 2022

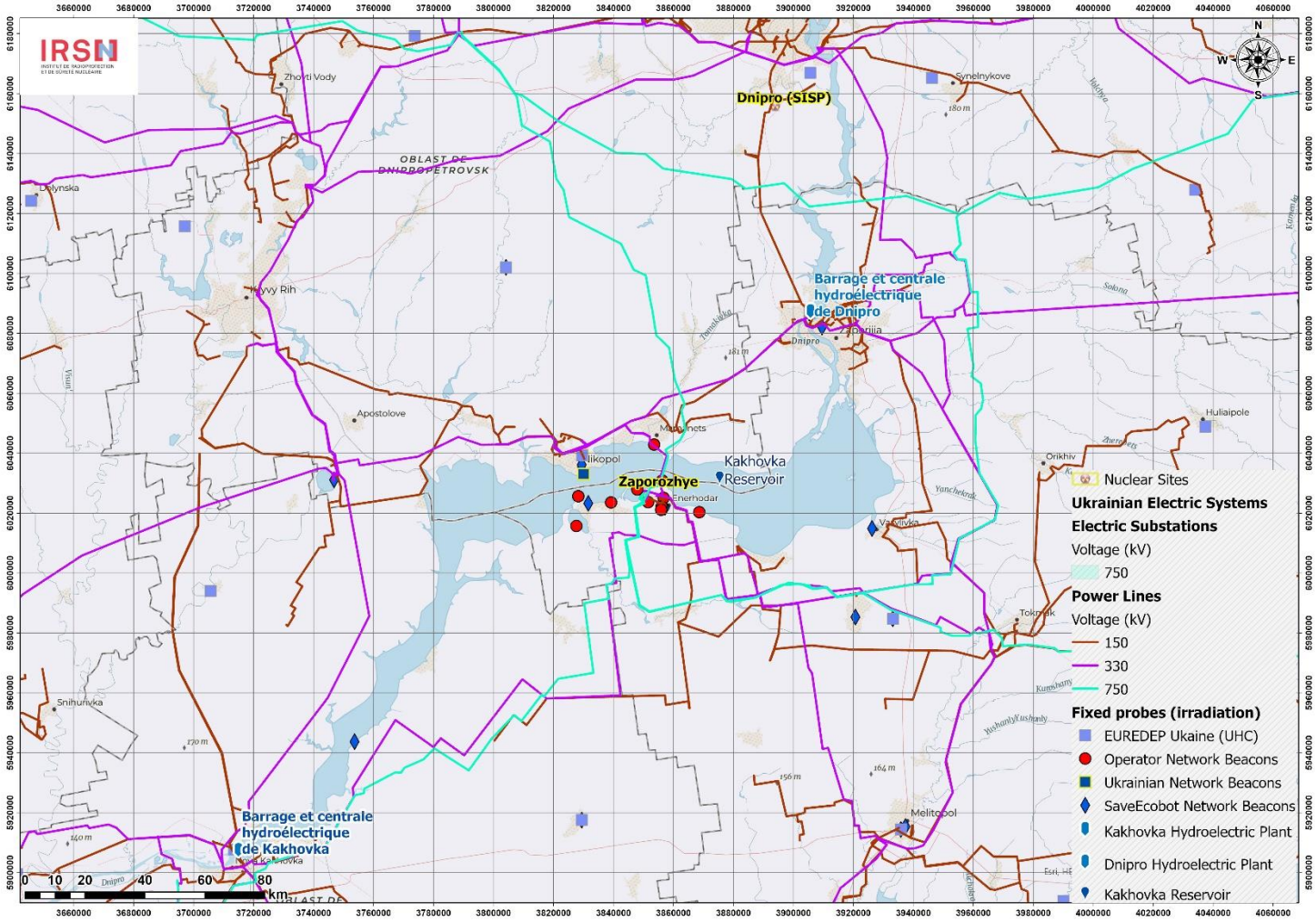

Figure 1 - Overview of the Zaporizhzhya nuclear power plant and its environment

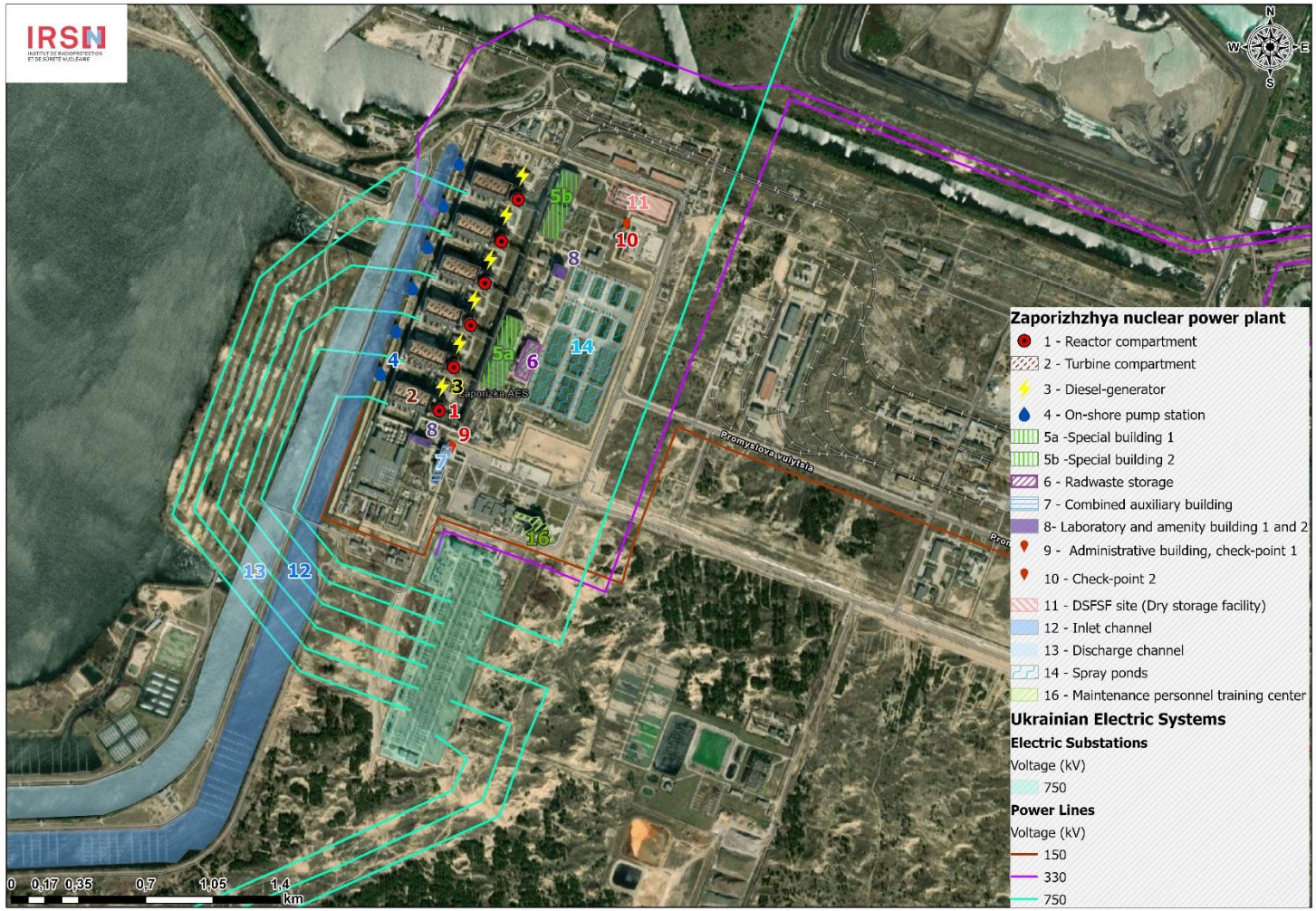

Figure 2 - Plan of the facilities of the Zaporizhzhya nuclear power plant

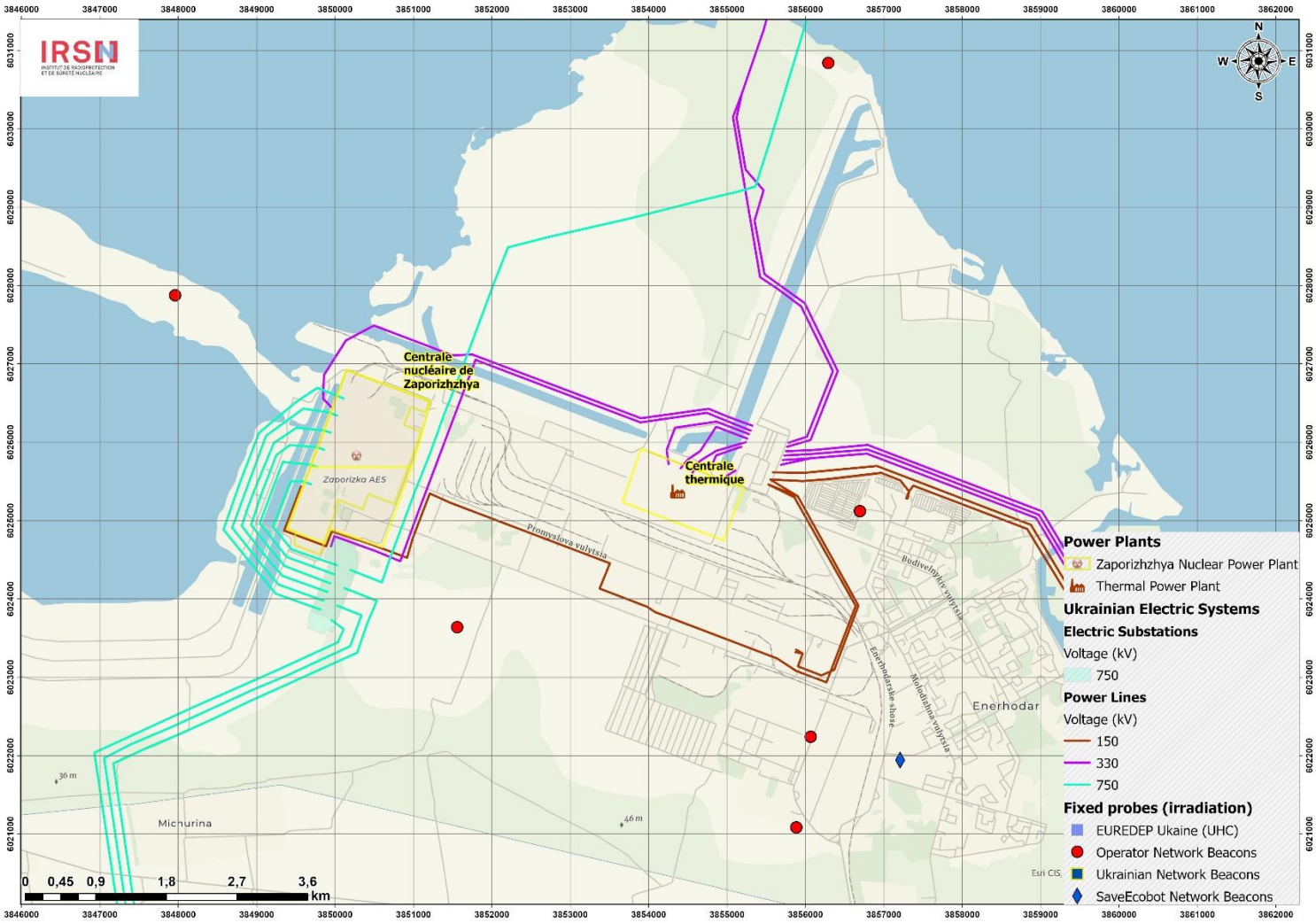

Figure 3 - Map of power lines connected to the Zaporizhzhya nuclear and thermal power plants