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INSIGHT

Russian Military Actions at Ukraine's Nuclear Power Plants

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Russian military forces have seized two of Ukraine's nuclear power plants as part of the invasion that began on February 24, 2022. The four-unit Chernobyl nuclear plant, whose last operating reactor permanently closed in 2000, was occupied on the first day of the invasion. Russian forces then attacked and captured the Zaporizhzhia nuclear plant, with six operational reactors, on March 4, 2022. Shelling caused damage and loss of power to the building housing the Kharkiv subcritical research reactor, which was shut down. The International Atomic Energy Agency (IAEA) has assessed that the "physical integrity of facilities, the ability of operational staff to work without undue pressure, and the access to off-site power … have been seriously compromised." Congress may wish to consider what actions the U.S. government could take to support international efforts to secure the safety and security of nuclear facilities in Ukraine.

Nuclear Power Plants Operating in Ukraine

Ukraine has four operating nuclear power plant sites with a total of 15 reactors, which in recent years have provided about half of Ukraine's total electricity generation. All the operating Ukrainian reactors are light water reactors (cooled by ordinary water), using designs developed in the Soviet Union similar in concept to most of the world's commercial power reactors. Ukraine's operating nuclear plants are located throughout the country, as shown by the following IAEA map:

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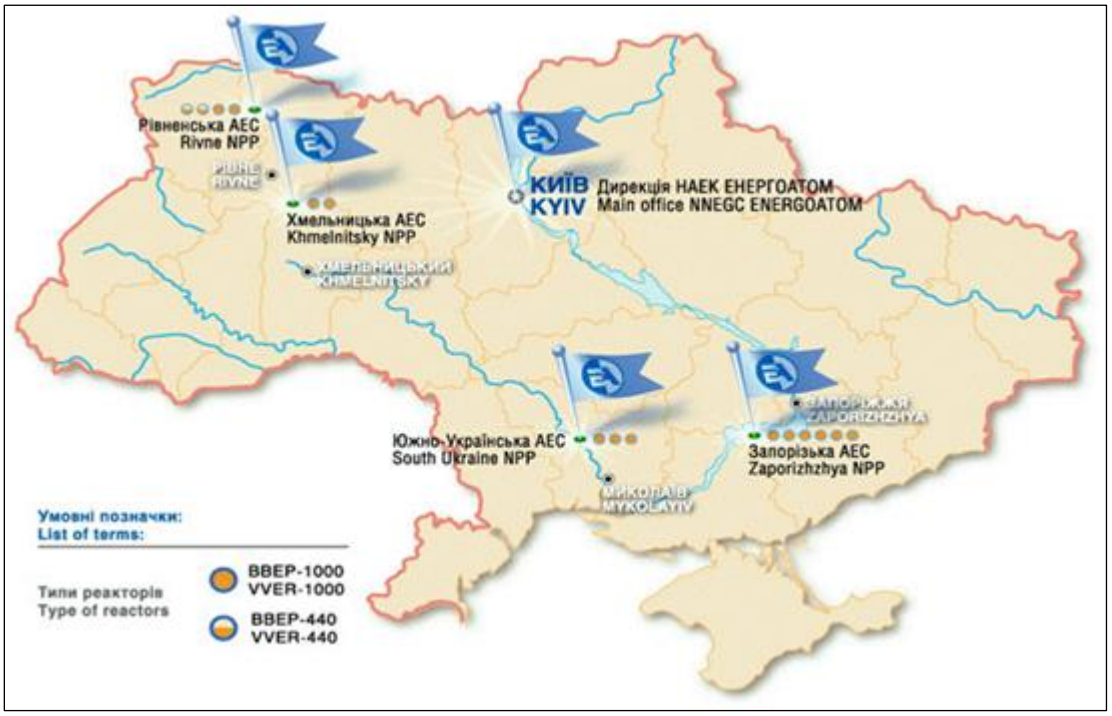

The 15 operable Ukrainian reactors are of a fundamentally different design than those at Ukraine's closed Chernobyl plant, where the Unit 4 reactor experienced an uncontrolled power surge in 1986, causing an explosion that released large amounts of radioactivity into the environment.

Reactor Safety Systems

The core of a light water reactor, such as those currently operating in Ukraine, consists of about 100 tons of highly radioactive nuclear fuel producing tremendous heat through a nuclear chain reaction.

To slow or shut down the chain reaction, control rods are inserted into the reactor core. Shutdown happens very quickly in an emergency. However, even after the chain reaction stops, substantial amounts of heat continue to be produced from the radioactive decay of the nuclear materials in the reactor core. If water does not continue to circulate through the core, decay heat can build up enough to melt the nuclear fuel and breach the steel pressure vessel that holds the core. The heat and pressure could also eventually escape the concrete containment structure that surrounds the pressure vessel and associated pumps and piping. This occurred during the Fukushima Daiichi accident in Japan at reactors built with a different type of containment from those in Ukraine.

Highly radioactive and thermally hot spent nuclear fuel is regularly removed from the reactor core to be replaced with fresh fuel. The spent fuel is stored in large pools of water adjacent to each reactor. The water must be constantly cooled to carry away decay heat from the spent fuel.

Reactor Safety Risks from Russian Attacks

The Russian military attack on the Zaporizhzhia nuclear power plant in southeastern Ukraine reportedly began with "heavy fighting and artillery shelling." The shelling started fires on the site that severely damaged a training building, but were extinguished without causing radiation releases. Russian forces seized control of the plant and its management, but the plant's operational personnel have remained on

duty "under constant psychological pressure," according to the Ukrainian nuclear regulatory agency. As of March 29, two reactors were operating and four were shut down.

The Chernobyl plant, located north of Kyiv, does not have any operating reactors, but the site includes large amounts of spent nuclear fuel and radioactive debris in a huge confinement structure that is guarded and maintained. The plant was reported to have lost power from the electric grid on March 9 and had to rely on backup diesel generators to power cooling and other systems until the grid connection was restored on March 14.

The ongoing Russian military action poses a range of potential threats to Ukrainian nuclear plant safety:

- *Direct military damage to one or more reactors*. Nuclear power plants are not designed to withstand military munitions, which could directly penetrate the concrete reactor containment and steel pressure vessel, allowing widespread release of highly radioactive material from the reactor core.
- *Military damage to reactor safety systems*. Even if a military attack did not damage the reactor containment, explosions and fires could disable the safety systems necessary to prevent the core from overheating.
- *Station blackout: loss of electric power*. Nuclear plants rely on electricity to run cooling pumps and control systems. If power from the electric grid is lost, diesel generators produce backup power and are intended to operate long enough for grid power to be restored. Loss of power from both the grid and the diesel generators results in station blackout, the condition that caused the radioactive releases at Fukushima.
- *Disruption of plant personnel*. Plant safety could be at risk if military action hindered or blocked the hundreds of workers needed to operate, maintain, and manage a nuclear power plant.
- *Damage to spent fuel pool or cooling systems*. If damage to a spent fuel pool allowed its water to drain, or if its cooling systems were disabled, the spent fuel could overheat and release large amounts of radioactive material to the environment.

International Response

At a U.N. Security Council meeting on March 4, the U.S. Ambassador called on Russia to withdraw its troops from the plant and ensure communication with regulators. The G7 leaders stated on March 24 that Russia must "refrain from any activity endangering nuclear installations."

The State Nuclear Regulatory Inspectorate of Ukraine reports on facility operations to the IAEA, which has "drawn up concrete and detailed plans for safety and security assistance to Ukraine's nuclear sites." In response to Ukraine's request, the IAEA Director General traveled to Ukraine on March 29 to meet with government officials and discuss delivery of "urgent technical assistance."

Some analysts argue that attacks on nuclear power plants could be considered a "war crime" under international law.

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