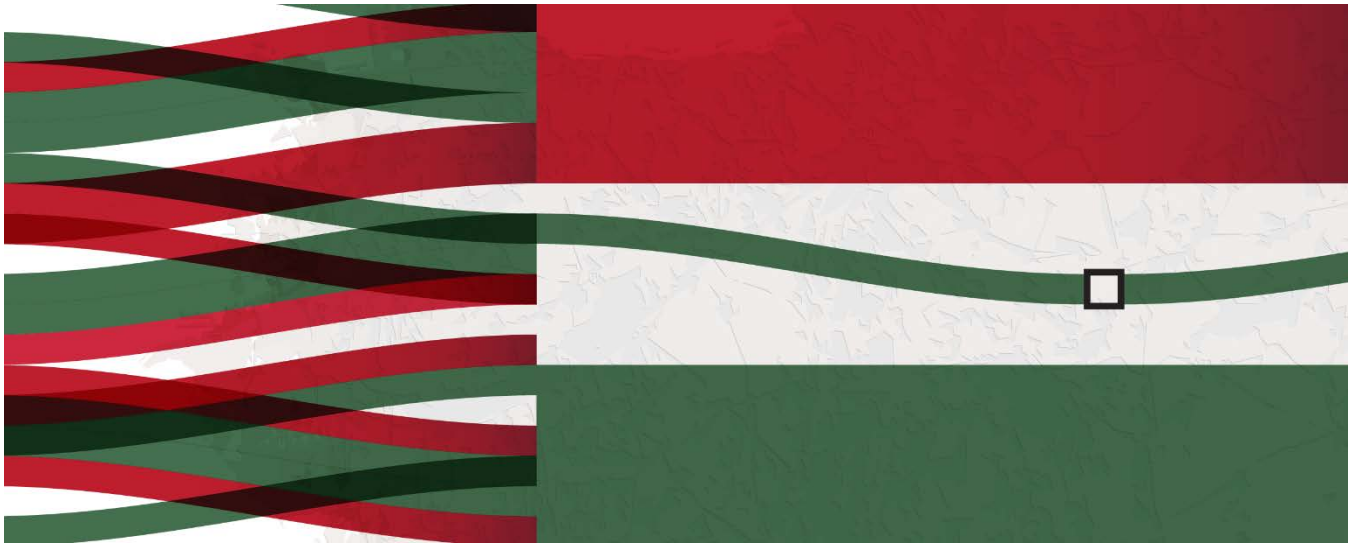
Building a Research Bridge to Hungary



By Brent Barker

Paks Nuclear Power Plant in Hungary joined EPRI's Nuclear Program in 2015 at a significant juncture in the nation's power system. The government had just granted life extensions to two of the four 500-megawatt VVER nuclear reactors at the site, about 130 kilometers south of Budapest on the Danube River. Paks was also in the initial planning stages to add in the 2020s two 1000-megawatt VVER units with a more advanced design—a move that could double Hungary's nuclear capacity.

In 2005, Hungary's National Assembly, recognizing nuclear power's central role in the nation's economy, passed a resolution to support life extension of its nuclear fleet, which was originally scheduled for a 30-year operation. In 2012, Paks Unit 1—online since 1982—was granted an extension to 2032. In 2014, Unit 2 was extended to 2034. Units 3 and 4, far along in the review process, are applying for a 20-year extension. The four nuclear units represent 51% of domestic electricity production. Coal accounts for 21%, gas 18%, and renewables just under 10% (see graphic).

"By joining as a full member of EPRI's nuclear power sector, Paks is able to tap into the complete range of our research related to long-term operations, aging management, fuel reliability, waste management, radiation protection, and risk and safety," said Neil Wilmshurst, EPRI vice president and chief nuclear officer.

Benefits of Membership

"The Paks staff has long known about EPRI and its nuclear programs and had been in touch for many years before joining," said Vaclav Vyskocil, EPRI International's country manager for Central Europe and Scandinavia. "One key inducement was that they operate the same VVER 440 reactors as CEZ, a Czech Republic power company that has benefited greatly from its five years of membership in EPRI's nuclear program."

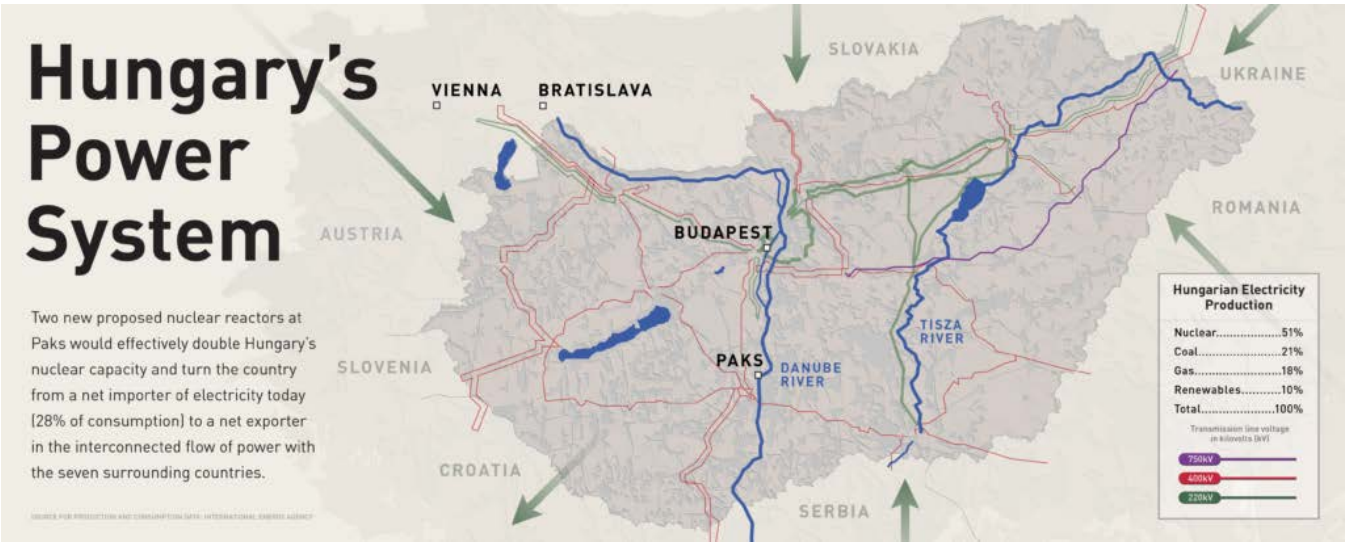
"Within weeks of joining, Paks staff became active participants," said J. P. Sursock, senior technical executive with EPRI International. "They participated in meetings, asked questions, downloaded reports, and were eager to interface with us in a number of fields—especially fuel reliability and life extension. And they have been very interested in talking with their counterparts in the West. EPRI offered them an opportunity to increase their interactions with the larger global nuclear community and further integrate their technical knowledge and operating experience."

Maintenance practices were of particular interest. Following a site visit to Paks by EPRI's lead maintenance program manager, the Paks staff are applying EPRI software and methods originally developed to support U.S. utilities in implementing the Maintenance Rule. This is part of ongoing work to apply similar rules in Hungary, which requires rigorous routine maintenance and continuous monitoring.

"Paks staff participated in EPRI-organized workshops in the U.S. as well as Europe," said Vyskocil. "They were active in the Equipment Reliability Workshop in Luhacovice, Czech Republic, in September 2015 and recently at Senec, Slovakia; the Fuel Reliability International Meeting in Prague in November 2015; and the annual Maintenance Rule Users Group in Charlotte, North Carolina. They became active participants in the Nuclear Power Council meetings, benefiting from personal contacts and technical exchanges with other members."

During Paks' first year of membership, EPRI conducted meetings on site to familiarize their staff with various EPRI products and programs, including equipment reliability, nondestructive evaluation, and risk-informed in-service inspection.

When offered the opportunity, Paks eagerly agreed to host EPRI's International Nuclear Power Council meeting in Budapest in June 2017, to be followed by a visit to the Paks facility.



EPRI's Growing Fleet of VVERs

The benefits of Paks' membership flow in both directions. The nuclear facility is strategically important to EPRI as it continues to diversify the operating experience of its members worldwide. EPRI members now represent 327 reactors. With Paks' four reactors, EPRI's collaborative R&D now covers 14 VVERs. CEZ was the first VVER operator to join EPRI, with four 500-megawatt units at Dukovany and two 1000-megawatt units at Temelin. The Slovakian Electric Company, a member of EPRI's nuclear maintenance and engineering programs, operates four VVER 440 units.

"The Paks membership means more VVER members with the same technology and therefore more VVER research funding," said Vyskocil. "It enables us to marshal resources and build a more effective collaboration with our VVER members."

The most common design is the VVER 440 and the VVER 1000 used in Hungary, the Czech Republic, and Slovakia. These reactors operate throughout Russia and in Ukraine, Finland, and Bulgaria. Newer, larger VVER plants are expected to come online in Turkey, India, and China.

"The VVER has many similarities to the U.S. and European-designed pressurized water reactors [PWRs]," said Sursock. "These include the basic heat cycle and safety features with several barriers for defense-in-depth—cladding for the fuel, the reactor vessel itself, and the containment to prevent release of radioactive material into the environment in case of a severe accident. But they also have significant differences, including major component design, construction, materials, and chemistry."

Key differences include:

- **Steam generators**. The most common VVER designs (500-megawatt units) have six primary coolant loops, each with a horizontal steam generator. The newer designs (1000-megawatt units) have four such loops. In contrast, western PWRs have two to four primary coolant loops with vertical steam generators. This leads to substantial differences in the operation, maintenance, inspection, surveillance, and repair procedures for these components relative to their western counterparts.
- **Fuel assemblies**. VVER fuel assemblies feature a hexagonal geometry and a core arranged like a honeycomb while western PWR assemblies have a square pattern and a square core with clipped corners. Fuel enrichment is typically lower relative to western fuels, but Paks recently implemented higher enrichment fuel designs to enable 15-month fuel cycles.
- **Safety features**. VVER designs incorporate interesting safety features not present in western PWRs. For example, a high-volume pressurizer creates a large thermal inertia in the primary circuit for additional safety margin.

Differences in water chemistry offer opportunities for beneficial R&D. Research related to primary system pH control is important for mitigating corrosion, maintaining good fuel performance, and minimizing plant radiation fields. While western PWRs use lithium hydroxide enriched in lithium 7 isotope (to greater than 99.99% lithium-7), VVERs use naturally abundant potassium hydroxide, which offers the advantages of a more readily available global supply and a substantially lower cost.

"Potassium use in primary water chemistry should be as effective as lithium in controlling pH, and may offer additional benefits for both materials corrosion and fuel performance," said Sursock. "Enriched lithium is currently produced only in China and Russia, and that could make western PWR operators vulnerable to a shortage if production were affected or global demand were significantly increased. Because of this vulnerability and the potential benefits of using potassium hydroxide, EPRI is conducting research on potassium so that western nuclear operators could be ready to implement that option if warranted."

While both VVERs and western PWRs use ferritic steels for the reactor pressure vessel, the steels used in VVER reactors have a higher nickel content. For reactor internals, both use various austenitic stainless steels, but VVER steels contain titanium while western PWR steels contain niobium.

"We are not as familiar with VVER materials as we are with steels used in western PWRs," said Sursock. "But we are actively working with Paks, CEZ, and the Nuclear Research Institute at Rez, near Prague, to expand our knowledge of the degradation and aging mechanisms of these materials and to develop mitigation approaches. We'll build on the methodology that has been developed for western PWRs."

Adapting EPRI Research for VVER Technology

To account for these differences, EPRI has modified some of its research products. For example, EPRI extended its Materials Degradation Matrix to include specific degradation mechanisms affecting materials used in primary circuit components in VVERs, along with recommendations relevant to long-term VVER operations. Two expert panels met in Prague in 2014 and 2015 to work on the Materials Degradation Matrix and related Issue Management Tables for VVER 440 and VVER 1000 plants. The panels included Paks, CEZ, various materials specialists, UJV Rez (Nuclear Research Institute of the Czech Republic), and EPRI staff.

Another important aspect of the cooperation between EPRI and VVER operators is safety analysis, such as the simulation of hypothetical accidents leading to core melt and their consequences (so-called “severe accidents”). EPRI’s Modular Accident Analysis Program, which simulates such accidents in western PWRs and other light water reactors, has been particularly useful in analyzing the Fukushima accident, understanding the unfolding of events inside the reactor, and developing guidance to help operators avoid or mitigate accidents. EPRI is completing a version of MAAP that incorporates VVER safety design features as part of developing accident guidelines for VVER operators.

To expand EPRI technical staff’s knowledge of VVER reactors, the Nuclear Sector in 2016 convened seminars in Palo Alto and Charlotte. “We brought in VVER specialists to explain the differences between VVER and western reactors with respect to design, materials, chemistry, and operations. Our technical staff are incorporating this knowledge into their research programs so that we will be more conscious of the specific needs of our members in Hungary, the Czech Republic, and Slovakia,” said Sursock.

“With EPRI membership, Paks gains access to products, technology, and best practices to help them successfully navigate life extension and enhance equipment reliability,” said Vyskocil. “It provides the Paks staff with access to PWR operators around the world and brings their expertise to bear on EPRI’s growing interest in VVER technology. EPRI’s entire global nuclear collaborative also benefits from a larger international engagement.”

Key EPRI Technical Experts

J.P. Sursock, Vaclav Vyskocil