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The Switch

Dr. Panu Kurronen is Chief Technology Officer at The Switch in Finland. Prior to joining the company at its very start, Dr. Kurronen worked as a technical manager at Rotatek Finland Oy, one of the three companies that initially merged to form The Switch in 2006. Panu graduated as a Doctor of Science (El.eng.) from Lappeenranta University of Technology in 2003. Over the years, he has worked as a researcher, laboratory manager, and associate professor at Lappeenranta University of Technology. From 1995 to 2000, Dr. Kurronen worked as project manager at Kone Elevators. His focus has always been on the application of special electrical drive trains.

Pushing Limits: Solving Modern Engineering Challenges With Solid-Rotor Technology

TURBOMACHINERY: **What is solid-rotor technology, and how does it differ from conventional rotor designs?**

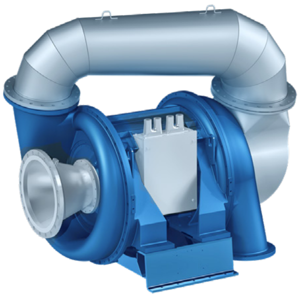
KURRONEN: In its simplest form, solid-rotor technology refers to an electric machine design where the rotor is made from a single solid piece of metal, rather than being built up from laminated steel sheets or multiple assembled components.

Depending on the application, the rotor can be used in its basic form or enhanced with features such as conductive end rings or a squirrel cage structure to improve electrical performance.

TURBOMACHINERY: **What are the key advantages of solid-rotor technology?**

KURRONEN: The main advantages come from mechanical robustness, stiffness, and simplicity. In conventional designs, such as laminated or permanent magnet rotors, you typically have multiple components on the rotor. As rotational speed increases, centrifugal forces grow rapidly, and even very small movements or imbalances can lead to higher vibration levels. This can damage the bearing or increase the load on active magnetic bearing systems.

With a solid rotor, the construction is much simpler. In its basic form, there are no laminations and fewer elements that can move or shift. This makes the



rotor inherently more stable under high centrifugal forces.

Another important advantage is thermal robustness. Solid rotors are less sensitive to temperature variations and do not rely on materials that can degrade or lose performance at elevated temperatures, which can be a limitation in some alternative rotor designs. Additionally, in many high-speed applications, solid-rotor technology enables direct-drive operation, eliminating the need for a mechanical gearbox. This further reduces system complexity, maintenance needs, and overall footprint.

Solid-rotor machines might not always be the absolute best in terms of electrical efficiency. However, in high-speed applications, this is usually secondary to reliability and mechanical integrity. In that sense, solid-rotor technology often provides the most practical and reliable solution.

TURBOMACHINERY: **What industry challenges or needs originally drove the development of solid-rotor technology?**
KURRONEN: The main driver was the need to operate at higher rotational speeds while maintaining reliable rotor balance. At the same time, there was a clear gap between lower-power applications—below 200 kW—and multi-megawatt systems.

At lower speeds—around 6,000 rpm—there are several viable technologies available. You can use laminated or permanent magnet rotors without major issues. But as speed increases, maintaining mechanical integrity becomes much more difficult. Solid-rotor technology was developed to address exactly this challenge, enabling higher speeds without compromising mechanical reliability.

TURBOMACHINERY: **How did this technology get its start, and what role did you personally play in its development?**
KURRONEN: The origins of this technology go back to research at LUT University in Lappeenranta, Finland. The doctoral work of Professor Juha Pyrhönen in the late 1980s laid the theoretical foundation for high-speed induction machines with solid rotors. My own involvement began as Professor Pyrhönen's first assistant, supporting the early research and further development of the concept.

On paper, we achieved promising results with a very simple rotor construction. The next step was to further develop the technology and improve its performance for real industrial use.

In its simplest form, a solid rotor is relatively basic in terms of performance. But by refining the overall machine design—such as modifying the stator, introducing slotting, and adding features like end rings or a squirrel cage—the performance can be significantly improved. Some of the solutions developed during those early years are still present in today's products.

TURBOMACHINERY: **Which applications have been most successful so far, and what makes solid-rotor technology particularly well-suited for them?**
KURRONEN: From a broader perspective, solid-rotor technology is best suited to applications where high speed is essential and conventional rotor designs begin to reach their practical limits.

The most successful applications so far have clearly been in compressor technology, especially vacuum compressors. These applications require high rotational speeds, compact design, and high reliability—all areas where solid-rotor technology performs well.

In addition to compressors, solid-rotor machines have also been used in various types of high-speed test equipment. To date, The Switch has supplied more than 1,000 high-speed solid-rotor machines for various industry applications with zero rotor failures.

***TURBOMACHINERY:* Where do you see the biggest untapped opportunities or "killer applications" for the technology?**

KURRONEN: One of the most promising areas is related to the energy transition, particularly in CO_2 and hydrogen compression. Hydrogen, for example, has a very small molecular size, which means that achieving efficient compression requires either very high rotational speeds or multiple compression stages. This naturally favors technologies that can operate reliably at high speeds.

Another important opportunity is in megawatt-class heat pumps. These systems are becoming increasingly relevant, especially in Europe, where there is a need to reduce reliance on fossil fuels and improve energy efficiency in industrial processes and district heating.

Heat pumps are highly efficient systems. For example, they can produce several units of heat from one unit of electricity. Scaling this concept to industrial or grid-level applications creates a strong demand for high-speed compressors, where solid-rotor technology can play a key role.

Energy storage is another area with big potential. For example, flywheel energy storage systems are becoming a viable alternative to traditional chemical battery systems and can benefit from high-speed solid-rotor technology.

***TURBOMACHINERY:* What is your long-term vision for solid-rotor technology over the next 5–10 years?**

KURRONEN: For many years, we have been expecting high-speed solid-rotor technology to see wider adoption, and I would say that we are now closer to that point than ever before.

The strongest potential, in my view, is in large-scale heat pumps and energy-related applications. These technologies are driven by the need to improve energy efficiency and reduce dependence on fossil fuels, and they are likely to grow over the coming years. That said, the pace of development is always difficult to predict. Many of these markets have been expected to expand quickly, but in reality, progress has been somewhat slower than anticipated.

Still, the underlying drivers are clearly there. If these applications scale as expected, solid-rotor technology is well positioned to support them.