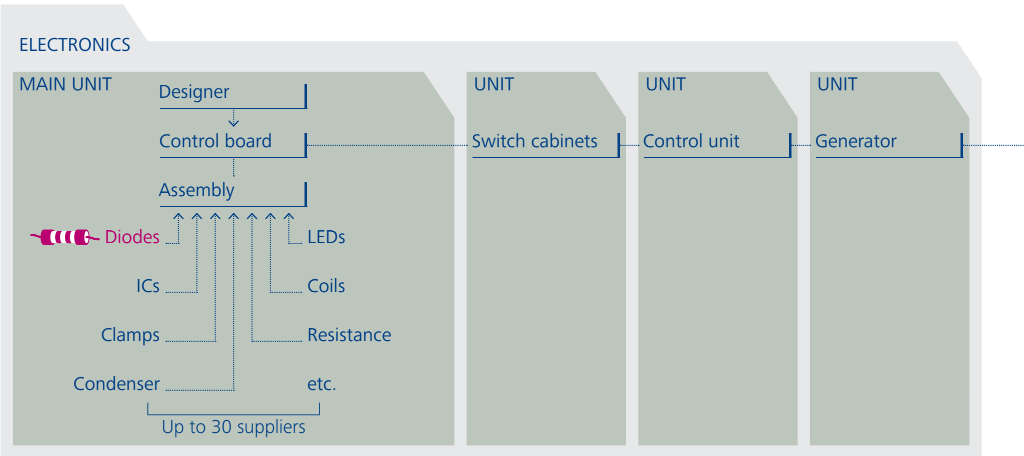
Debugging – successfully

Small but by no means unimportant: defective electronic components can lead to malfunctions, not only in computer systems but also in entire transportation systems or power plants, and as a result incur enormous expense. Troubleshooting is generally very difficult, especially if the components don't exhibit any manufacturing defects. Experts at Empa are playing the role of detective for industry and have taken causal research to the highest level.

TEXT: Martina Peter



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In a complex electronic system, thousands upon thousands of components and modules must work together smoothly. If there's a system outage, virtually an infinite number of errors could be responsible; for some individual microchips around 400 failure classes have already been defined. It's almost like trying to find the proverbial needle in a haystack when – as recently happened in a wind turbine – for no apparent reason, perfectly good diodes start failing on a regular basis.

That's a problem right up the alley of Empa researcher Peter Jacob, who joins with other experts in microelectronics, and together they use their skills as sleuths to investigate such failures as well as to uncover weaknesses in components, circuits and their applications. In the process they bring some surprising results to the light of day. The team from the Electronics/Metrology Laboratory operates as do specialised physicians in a group practice. The "patients" of Empa's Reliability Network are components and modules from power electronics, microelectronics and optoelectronics. "We receive enquiries from industrial customers who frequently expect the worst," according to Jacob. That's because many fear extremely high costs as a consequence of a system failure.

As would a doctor, the Empa experts first conduct a diagnosis meeting. They examine factors such as how the interconnections in the application are laid out, who delivered the modules or how long a component has been in use. In the case of the wind turbine, however, neither did the components exhibit manufacturing defects nor did the schematics reveal any defects. Nonetheless, small diodes were failing in the same location in a module with integrated rectifiers. Redundant systems – a type of replacement system which steps in if there is ever an operating malfunction – prevent higher level components, in this case the generator control system, from being affected. Even so, the continuous repair work proved extremely time-consuming and expensive in the remotely located wind turbines. It was thus the proper time to commission the Empa experts to search for the actual cause of the failure.

Painstakingly detailed detective work

Constructing a technical system such as a wind turbine is almost as complicated as the control systems it contains. One supplier erects the tower and turbine blades, while another develops the required control systems, which in turn contain countless electronic components from further manufacturers that are finally assembled into the overall control system by a further partner in the manufacturing chain. Having 30 or more suppliers involved is not unusual.

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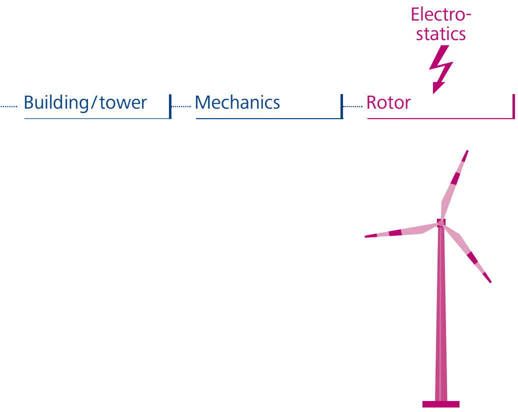

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In a complex electronic system, the search for the actual cause of the failure needs painstakingly detailed detective work. In the case of the wind turbine, it was the electrostatic charging of the rotor which led to the failure of the diodes.
(Illustration: André Niederer)

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Especially in remote locations, the repair of failed electronic components can become time-consuming and expensive.
(Photo: Beatrice Huber)

This results in numerous interfaces, and errors can creep in at each one.

When Jacob or one of his colleagues want to physically analyse failed components and modules, they have at their disposal an arsenal of investigative equipment and manipulation processes for microstructures which is virtually unique in all of Switzerland. First they attempt to localise the failure in the component, which is generally a microchip the size of a fingernail and which has millions of transistors. If they are unsuccessful, they turn to a systems analysis. "Sometimes it's the apparently unimportant but instead rather random details which put us on the right track," explains Jacob.

In the case of the wind turbine, additional discussions with the responsible engineers led him to the solution of this puzzle. They reported to Jacob, among other things, an observation in the rotor's grounding system which in their eyes was of no real consequence, but by doing so they provided the Empa "investigators" with the missing piece of the puzzle. It was the electrostatic charging of the wind turbine which penetrated into the shaft and thus led indirectly to the failure of the diodes. A large rotor diameter creates large electrostatic voltages on the rotor axle. If this is not properly grounded, tiny sparks jump across, and they are coupled as voltage impulses into the electronics through the cabling conduits. These finally led to the diodes encountering an early demise.

The solution was to set up proper grounding, optimise the conduits to avoid interference with large impulses from neighbouring circuits and to add additional protective elements to the circuit at certain points – and with this, the mystery was solved. //

Empa's Reliability Network

At Empa, industry partners can find experts who can help them answer complex questions about quality and reliability regarding materials, components, equipment and systems. In doing so, the experts turn to equipment and methods such as focused ion beam (FIB) systems, scanning electron microscopes and transmission electron microscopes, special preparation and grinding machines as well as thermal laser stimulation and infrared thermography. Numerous corporate clients – especially small and mid-sized enterprises – have joined this "industry pool" whereby they can, as required, fall back on the assistance of the Reliability Network as well as a further Empa analysis centre, the ZZfP (Center for Non-Destructive Testing).
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