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Interview with **Senja Leivo**

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VAISALA

**Moisture in solid insulation,
the bane of dielectric strength**



Alan Ross: My name is Alan Ross, I am the Managing editor of APC Technologies, and my guest today is Senja Leivo from Vaisala.

Senja Leivo: Thank you, Alan.

AR I'm going to ask you a true or false question as a scientist. Every 1% increase of moisture inside of a transformer degrades the paper by half. True or False?

SL Yes, I would agree, this is like a rule of thumb.

AR This was an IEEE statement 20 years ago, and most people don't realize it. Whether it's by half or 20%, what it really says is *moisture* in a transformer is not good, correct?

SL Yes, exactly.

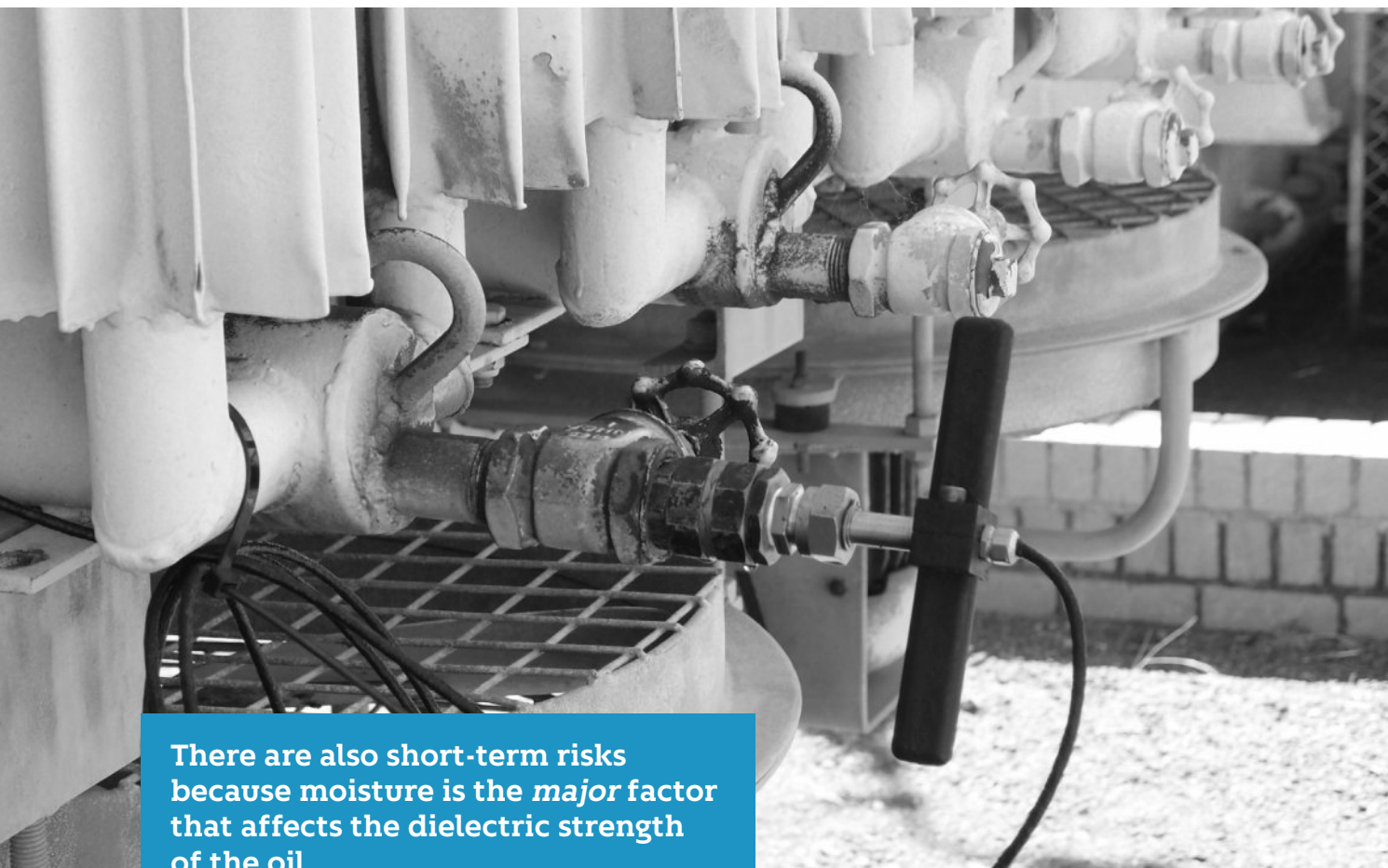
AR Where does the moisture come from?

SL After factory drying, there is always residual moisture, which is very small. However, it is very difficult and noneconomical to dry it completely. Transformers are really dry when they arrive on-site, and during the lifetime of the transformer, I would say the

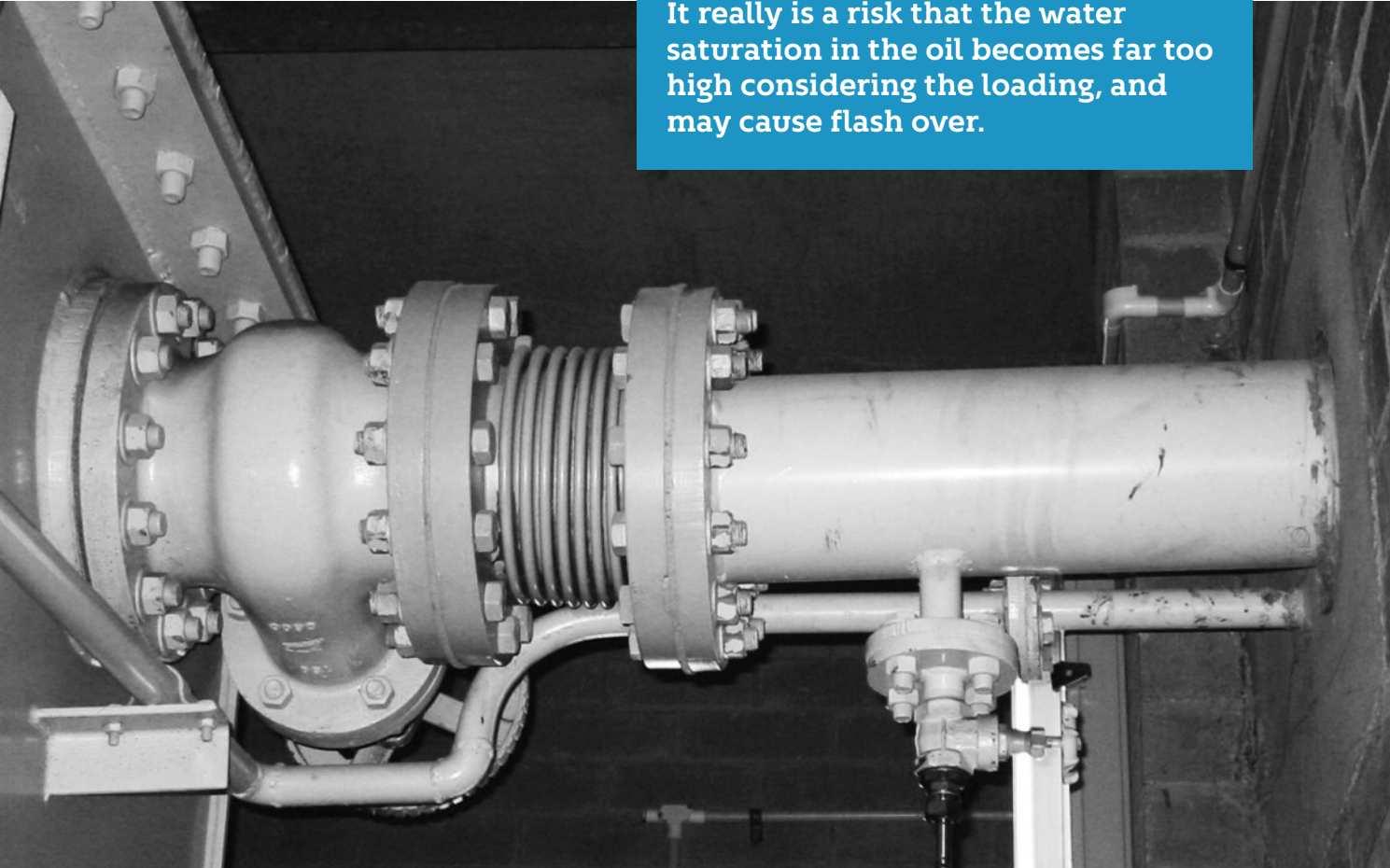
majority of the moisture comes from the surroundings, either from ambient air humidity or some rare cases rainwater.

AR Okay. Most of the insulation products are cellulose based in transformers. And as I understand it, there's more moisture potentially trapped in the cellulose than there is in the oil. The oil may be dry, but if the cellulose has got moisture in it, as you said, that's going to migrate out. Talk about moisture in general as it relates to transformers and operating transformers. Just give me a primer on that.

SL It's exactly like you said Alan, cellulose materials especially insulation paper are very hygroscopic. The water will go there, regardless of the insulation liquid, whether it's mineral oil or esters. And only a small portion of the water is in liquid. It's said that 99% of the water is in solid insulation, and when the transformer is operated and when the temperature varies, some of the water is released from the insulation paper surface to the insulation liquid. Therefore, if we follow the water content in liquid in real-time, we can see fluctuation. As temperature varies, we see variations in water content in insulation liquid. It's never in thermodynamic equilibrium unfortunately when it comes to operational transformers.



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AR Here's the problem. I don't think the industry understands how bad this is because I talk to people and ask them if they test for moisture in their transformers. They respond with "Why would I do that?" I think there's a real ignorance about the damage that moisture in transformers does.

SL There are basically two major issues. One is the paper degradation in long term, as you mentioned. The other issue is more related to the operational conditions of the transformer. There are also short-term risks because moisture is the *major* factor that affects the dielectric strength of the oil. Especially if we have a wet transformer that has a lot of water in its solid insulation.. Then in some conditions you may be at risk of having a breakdown because of moisture in the oil.

AR What's the problem with the annual or quarterly or semi-annual lab testing as it relates to moisture?

SL It's often that the sample is just once a year or once in two years. As I mentioned, the moisture is exchanged between oil and paper. It's continuous, and you may not see those extremes with periodical samples. Also, quite often the samples are missing the

temperature information, and in order to be able to evaluate the meaning of the water content in the oil, you really have to know the oil temperature, when the sample was taken because like I said, it varies a lot.

AR Talk to me like I'm a risk manager at a company and explain to me what the risk to my company would be and to my asset which is the transformer if I don't manage the moisture.

SL If it's an older transformer, and if the solid insulation has a high level of water, or if that transformer needs to be loaded heavily for some reason - Let's say there is a sister transformer that needs to be put out of service, and all the load is put to the other one which is wet. In this case, with such a quick high loading, the water is pushed from the solid insulation into the oil. It really is a risk that the water saturation in the oil becomes far too high considering the loading, and may cause flash over. Another similar issue may occur. If we have a wet transformer that was out of service for a while and when it's put back online and loaded quickly, the oil is still cold it cannot hold that water that is pushed from the winding insulation. And you can really have a so-called "raining" in a transformer. That for sure will cause a breakdown.

AR I want to switch gears a little bit. We're trying to decentralize energy, right? We're trying to go wind and solar. Those transformers become more like inverters than transformers because they must take power in. Is there a greater risk to an inverter-based system because of moisture, or is it just the same? What do you think?

SL If we only think about the basics, like thermodynamics it's the same, it doesn't matter which direction it goes. If it's a question of moisture, it's a question of temperature, it's a question of the materials involved. But all in all, I would say it's the same.

AR My next question then is, how do I mitigate the risks of moisture in transformers?

SL The first thing I would say is to get a good picture of the moisture levels, and the overall moisture dynamics in a transformer by having online monitoring to really see what is the moisture level during the normal operating conditions of the transformer, and if there are risks like the relative saturation of moisture going too high. One option would be to apply an online dryer to that transformer.

AR IEEE has now made passive drying one of the *primary* functions of eliminating moisture in a transformer. And there's a lot of them, a lot of them being made by different companies. It's a cost-effective way as it really works. Moisture tends to escalate and it tends to move with temperature, load, and everything. Therefore, it's the trend lines of moisture monitoring.

SL Yes, that's true. But even following trend is challenging because the desorption of moisture from paper to oil is faster than the absorption of water back to paper. So just comparing temperature and moisture levels is not so straightforward as you would think. But obviously, when you have real-time monitoring and you have the loading data and you have the temperatures, you can get a clear picture of the overall moisture household in the transformer and if there are risks involved short term or long term.

AR Vaisala is arguably one of the world leaders in monitoring technology. Tell me about what has happened in the whole monitoring as it relates to moisture. What technology should I be looking for?

SL I think nowadays basically all online moisture sensors are using the same technology principle, which is the capacitive

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moisture sensors, which basically measure the relative moisture saturation of oil and the temperature and if needed it calculates the absolute water content as ppm.

We started doing real-time monitoring 20+ years ago. If I look back at that time, it was more challenging to convince the asset owners that online monitoring of moisture could be useful.

AR We both agree that moisture in transformers is often overlooked, and misunderstood and it's a real problem that transformer owners, and transformer operators really need to know about. There is no way to deliver a transformer that is



completely moisture-free unless you want to pay a lot more money than you already do for the transformer. Therefore, the idea of monitoring moisture is an important one. It is one that can be coupled with DGA monitoring so that it becomes simpler, but it gives you the data and the information that you need in order to make a decision. Is that a fair statement?

SL Yes, I would agree. But even more, I would say that for new transformers, I really encourage the asset owners to pay attention to the early life of the transformers because like I said, the moisture comes from the surroundings. And by taking care of the breathing systems, taking care of the dehydrators of the breathing systems are in good condition, you can really extend the life. But once the transformer is already wet and

has high water content in its solid insulation, then I would say the online monitoring becomes more and more important because that's where the operational risks may come up.

AR Last question, moisture in oil, moisture in esters. Is there a difference between oil and esters in terms of what happens with the moisture? Is it better? Is ester a better solution to treating moisture and transformers at the beginning? Or is that a myth that esters are better?

AR Okay, great thank you very much for that answer. This has been a great interview. Thank you for the work that you do and thank you for willing to share that with us at APC Technologies.

SL Thank you, Alan, it was a pleasure to be here.



Once the transformer is already wet and has high water content in its solid insulation, then I would say the online monitoring becomes more and more important because that's where the operational risks may come up.

SL That's a question I've been asked a lot, and I don't want to take any specific opinion. However, looking at this from a scientific point of view, it's true that esters, synthetic or natural, have much higher water solubility than mineral oils. But after all it is water content in paper and transformer temperature that determines what will be the relative moisture saturation in insulation liquid whether it is mineral oil or ester.