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LUC PAULHIAC

Chief transformer expert at EDF

Transformers Magazine features an interview with Luc Paulhiac from EDF. Luc, thank you for the opportunity to speak with you. First, I'd like to ask you what your position in EDF is and what your responsibilities are in the company.

I'm working at the corporate level for the French PWR (Pressurized Water Reactor) nuclear fleet (56 reactors including 32-900 MWe units, 20-1300 MWe units and 4-1450 MWe units) as a senior expert in a Maintenance Support Department. Since 2007, I have been responsible for all equipment located between the main generator and the grid (TSO-Transmission System Operator): Isolated-phase bus (IPB), power transformers, and switchyards (AIS-Air Insulated Switchyard and GIS-Gas Insulated Switchyard technology). My responsibilities are mainly the daily operational support of nuclear power plants and the definition of the entire maintenance and renewal strategy (asset management). I also manage R&D programs and deal with all the specific regulations that govern these systems, the most important of which is, without doubt, the regulation relating to greenhouse gases (FGAS). Exercising this role allows you to have a real-time and long-term vision of many aspects (technical, industrial, regulatory, etc.) but also means being constantly interrupted to solve problems.

Thank you. Can you explain the fleet of transformers in EDF nuclear? How many transformers do you have, and how are they installed? What are their ratings?

Basically, each power plant has five ODAF transformers, one step-up transformer, which is made out of three single-phase transformers and two three-phase transformers called UAT and SAT. The role of the UAT/Unit Auxiliary Transformer (UAT) is to power all the electrical auxiliaries of the nuclear unit; the role of the Emergency Auxiliary Transformer (SAT), always energized but without load, is to provide backup for the UAT. For the 900 MWe units, the rating of each step-up one-phase transformer is 360 MVA (400 kV to 24 kV), and for all the 24 other units, it is 570 MVA (400 kV to 20 kV). Depending on the power plant, the rating of the UAT goes from 48 to 96 MVA (225 kV to 6.6 kV and 400 kV to 6.6 kV), and the rating of the SAT goes from 29 to 64 MVA (225 kV to 6.6 kV and 400 kV to 6.6 kV). There are a few other transformers that will soon come into my scope, including 650 MVA single-phase transformers from the latest nuclear plant. To summarize, I find myself at the head of a fleet of more than 310 transformers.

In a way, this is not a lot of transformers, but if we consider that in a nuclear power plant, the failure of a single transformer means that the complete plant must be shut down, involving daily production losses of several million euros (€3-5 million/day up to €20 million/day in winter, depending on prices of MWhe). We understand that failure is not the best option...

I have heard that EDF is a demanding utility, a utility with quite strong and detailed transformer specifications. I guess there are specific reasons for such strict specifications. Can you explain the expectations and the requirements for your transformers which are reflected in those specifications?

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We buy up to several dozen devices and not just one. This means that errors in specification, design and manufacturing can have very serious consequences in terms of daily production losses but also in terms of collateral damages. The requirements for our transformers are based on IEC standards but also on our knowledge and, above all, on what we have learned from the breakdowns of our transformers. Standards are a good starting point but are sometimes not sufficient since they are the result of a consensus and do not necessarily (or too late) reflect the knowledge acquired.

For these reasons, we really need to go in-depth into all the aspects of the design and qualification: thermal, dielectric, mechanical (even mockups), arc withstand, and so on.

Another difficulty/challenge we face is regulations (such as the EU Ecodesign Directive) whose requirements run counter to expectations in terms of features required by our design rules. For example, UATs must meet certain criteria relating to their impedance in order to limit the impact of a failure on the powered equipment, which the legislator does not really understand.

When we speak about specifications and requirements, buying transformers on the market nowadays is not an easy task. How are you dealing with this?

With my previous answers, we understand that we are a complex and demanding customer and that our specific needs may possibly make it difficult for manufacturers to understand and translate our needs into their "standard" design. This also goes hand in hand with the complexity of organizing activities in nuclear power plants. I think the best way to solve this problem is to establish long-term partnerships with your manufacturers. The time from contract to transformer construction is lengthening, especially now that there is a shortage of manufacturers due to the growing need for transformers and skyrocketing raw material prices. I am glad that we are almost finished renewing our transformers because undertaking the same program now would be much more complex and costly.

When you speak about these challenges in buying new transformers, can you tell us about the biggest challenges that you have experienced with transformers during the last 10 years? What can you expect in the next 10 years?

The biggest challenge is really to make manufacturers understand that we must be partners. We must not only talk about contracts, not only money, but we must speak the same common language, which is physics. I am convinced that by talking about physics, we can reach agreements much more quickly on design issues (especially thermal) or any other design issues that might arise during negotiations. The problem is that every time something goes wrong, there is a temptation to hide behind "house rules." Who has never heard this ready-made answer every time there is a problem? In over 10 years of renewals and more than 240 transformers, I have heard it more than once. I think manufacturers need to understand that they must step out of their comfort zone because when you protect yourself with your existing rules, you're not trying to understand the scope of validity of those rules. Most of the time, it is failure that leads to progress and change in habits (sometimes painfully). The most important thing is to be open-minded, and the key point of a good customer-supplier relationship is to find a common point of discussion, which is a physics-based language.

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The other lesson learnt is that the best way to solve problems is by adopting the supplier's language, by showing them that we have mastered our requirements and the means to achieve them, and above all, by organizing short meetings with only the necessary people. And as always, a good drawing is better than any specifications.

Regarding the next 10 years, I am not a guesser, but I think that more than ever, we will have to make allowances for the complexity, which consists of finding the best path between financial, regulatory, technical constraints, and above all, a cost of the ecological transition which promises to be pharaonic, all in an uncertain economic and geopolitical context.

In such a market situation, one of the challenges or major risks is losing the existing transformers in the grid. Investment in new units is one thing, but you, as a transformer owner, have to make sure that you don't lose your existing operating transformers because you will face problems getting a new unit. What are you doing in order to prevent this situation? How do you maintain your old transformers? What is your strategy in this slide?

A good point is to fully understand and assess the condition of your existing transformers. We have, therefore, developed a lot in the field of aging markers, methanol, and ethanol in collaboration with IREQ (Hydro-Québec Research Institute) since the beginning of the 2000s. We have also developed our methods of defect identification from dissolved gases. Here again, having a large fleet of transformers, and also having access to other fleets (thermal and hydro generation) allows, through crises and expertise, to gather essential information on the effectiveness and relevance of the diagnostics methods. Michel Duval's triangles and pentagons naturally emerged as the most effective tools. Also, in the field, we must know how to integrate the advances proposed in the CIGRÉ Guides and/or the published methods long before they are included in the standards.

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We also need to change practices. When I started my job, dissolved gas measurements were carried out every 2 to 3 years. I changed the sampling frequency to 3 months and quickly used the online gas analyzers to manage crises. These new practices made it possible to intercept failures. Currently, we are in the process of equipping all the main transformers with online gas analysis, bushing monitoring, and thermal monitoring (in order to optimize cooling stages and maintenance with a view to extended lifespan nuclear power plants).

What is a good spare parts strategy for situations where maintenance is critical to reduce risks to the grid?

Defining a good spare parts strategy and volume is not an easy task. It depends on the failure probability (and failure scenarios), acquisition delays, and costs of production losses. Financial constraints are permanent and very strong. Inventories represent expensive financial assets, and a financier perceives them as a burden while the operator sees them as insurance.

Having a standardized fleet (transformers and switchyards) makes it possible to utilise spare parts in between quasi-identical installations

Having a standardized fleet (transformers and switchyards) makes it possible to utilise spare parts in between quasi-identical installations. However, it also introduces the complexity of the best location for spare parts and their transportation, especially in a country like France, which must be the world champion of roundabouts.

Having spare parts is only part of the equation. You also need to have trained and available people capable of sometimes managing technologies that are already 30 to 50 years old, which is particularly true for AIS/GIS switchgear. Therefore, you need to maintain close bonds with the OEM (Original Equipment Manufacturer).

In your positions, you are also responsible for knowledge management in the company. What best practices do you use?

We live in an astonishing world where getting information and knowledge has never been so easy. When I was young, whatever the subject, you had no more than 2 to 3 books to read to get a good picture of a given subject. Now, you have internet, databases, and videos for training, but what puzzles me is that no one can take this huge amount of knowledge and make something out of it. Too much information "kills information," and people are literally saturated with information that is sometimes contradictory. The easiest path is to do what you were told to do without questioning the credo, the house rule.

In my responsibilities, I often qualify companies on the technical aspect, and for this, the best strategy consists of asking why this or that operation is carried out in the way in which it is described in operational documentation. And unfortunately, most of the time, the answer is: "because" or "we have always done it like that." This shows that you can easily be doing something without understanding why and/or the limitations.

In many companies, but also in power plants, fewer than one or two people truly

master strategic knowledge. Consider this especially when most of these people are already retired and/or about to retire.

I think we must constantly ask ourselves the question of mastering our knowledge, not with the sterile aim of questioning everything, but with the aim of seeking permanent improvement. A questioning attitude is an essential quality in the field of technology; otherwise, we are just a parrot repeating what we have been told without understanding it. That said, I don't think I have the perfect solution, and I certainly don't want to lecture anyone.

My own strategy is to absorb knowledge and write subject guides in which you will find all the relevant information needed (equations, examples, OPEX-Operational Experience, relevant standards, regulations, etc.) for a dedicated task. I have written around ten basic guides (possibly accompanied by Excel sheets) on: the analysis of dissolved gases, insulation (liquid and solid), thermal evaluation of a transformer, conservator, Infrared, gaskets, tank welding, corrosion, electrical contacts, etc. These guides are used in the field and revised whenever there is a new regulation or in-field experience, etc. This shows that knowledge is not fixed but in constant evolution.

In the era of energy transition and decarbonisation, nuclear energy is not on the list of popular energy sources. You call this political correctness. What is your view on nuclear energy, and what figures do you base your opinion on?

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The debate must be dispassionate. When we talk about renewable energy, we must not forget to say that it is also intermittent, with availability in the range of 15 to 25% (at least in France), and that the means of storage are very limited to null. The best means of storage at the moment are PETS (Pumped Energy Transfer Stations) type installations, dams where the water is raised at night (when prices of electricity are low) to be able to deliver it during strong calls in the day. This means that we currently do not know how to do without the massive means of production available, whatever the weather conditions. In terms of LCA (Life Cycle Analysis), the CO_2 weight of one kWe in the generation is: nuclear (4 g), hydro (10 g), wind power (15 g), photovoltaics (35g), gas (400 g), coal (1000 g), etc. The reason why nuclear energy is coming back to the forefront is because the people have understood (beyond any political and/or dogmatic discourse) that we don't really have anything better to offer in terms of low mass production with low carbon weight but also in terms of production costs and use of basic materials. Other important data to consider is the spatial and material requirements for each energy source. In that sense, nuclear generation is the most optimal (source: https://energy.glex.no/feature-stories/area-and-material-consumption):

Energy	m²/kW	Material used in t/TWh	Critical metals in kg/TWh
Nuclear	4.1	930	19.89
Solar	150 (x36.6)	16457 (x17.7)	81.82 (x4.1)
Wind	543 (x132.4)	10260 (x11)	529.98 (x26.6)

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I do understand that data can always be criticized, but whatever the source, you cannot beat nuclear generation in terms of both area and material needed per kW generated. I don't want to ignore the issues of safety and very long-lived waste, which are also important elements to consider when dealing with nuclear generation, but it seems to me that access to carbon-free energy is a vital priority for our societies.

The carbon footprint of an electric car depends not only on its manufacturing (raw materials, energy, water consumption, etc.) but also on the origin of the electricity used to recharge it, and it makes no sense to use high CO_2 emission production means.

For those interested in real-time CO_2 emissions related to electricity production, you can easily download the Electricity-Maps app on Android.

Do you have any advice for anyone who wants to be involved in the transformers industry?

Understand and respect physics!