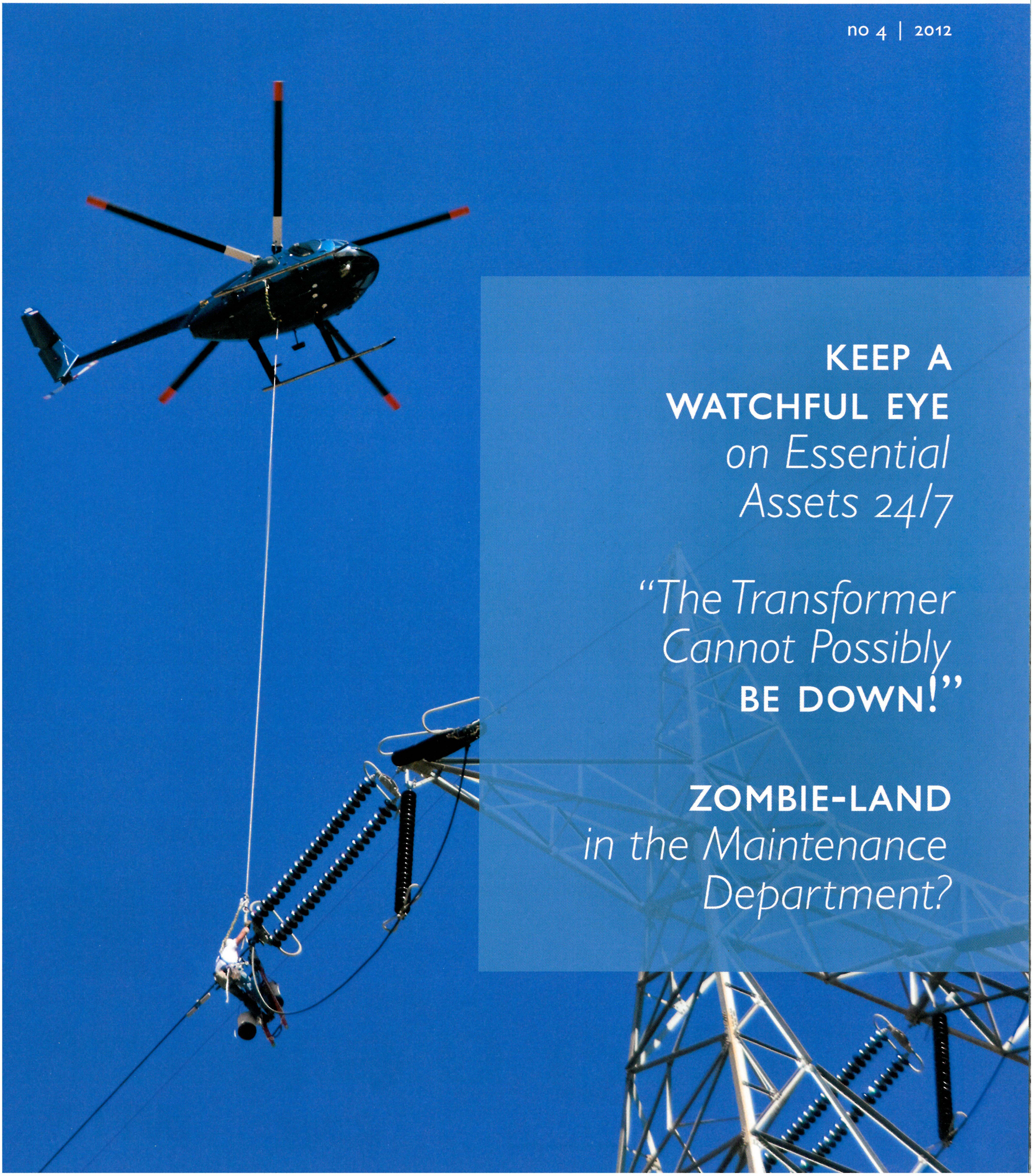
MAINTENANCE & ASSET MANAGEMENT

maintworld

no 4 | 2012



KEEP A WATCHFUL EYE *on Essential Assets 24/7*

"The Transformer Cannot Possibly BE DOWN!"

ZOMBIE-LAND *in the Maintenance Department?*

"The Transformer Cannot Possibly Be Down!"

Evaluating New Monitoring Solutions with a Business Case

"The transformer cannot possibly be down! The gas-in-oil analysis six months ago was fine." exclaimed an employee of an electric utility. The traditional gas-in-oil analysis is done once or twice a year, is labour- and cost intensive and does not offer real time information. It is like testing your blood sugar only once a month when you have diabetes.

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Diabetes is triggered by your genes and your lifestyle, you cannot change your genes but you can change your lifestyle. The same is true for transformers, i.e. weather conditions that are strenuous for transformers like lightning or extreme cold cannot be changed and need to be dealt with as they arise. But with smart maintenance solutions utilities can directly influence and efficiently enhance the asset management of their transformer fleet in advance.

Transformers are expensive resources and their breakdown causes costs that all electric utilities want to avoid. Many power transformers have reached and passed the critical age of 40 years, resulting in an increase in both breakdown risk and maintenance cost. Therefore, the crucial questions are how to extend the transformers' life as much as possible and how to decide reliably when the time for replacement, at a cost of several millions is best.

A utility was considering a new maintenance solution and with respect to these constraints one that would allow them to make more reliable decisions. They recently had an incident where they decommissioned a 35 year old transformer profiled as a "high risk transformer" in their fleet which had shown worrying results in the traditional gas-in-oil analysis. They took the transformer apart and were almost shocked to see it bright and shiny like new on the inside. Hundreds of thousands of Euros were wasted.

New Online Monitoring Solution for Utility Challenges

To find a maintenance solution to meet best the challenges, the utility decided to evaluate its effects on their asset management with a Business Case. The decision-makers were not interested only in technical features but their effects on risk minimization and cost reduction, and that could only be quantified with a Business Case. Due to this last maintenance "fiasco", they decided to change to online monitoring of the transformers in order to move from time-based to condition-based maintenance.

Online dissolving gas analysis (DGA) is not new. It has existed already for 30 years but still less than 5 % of power transformers worldwide are monitored by this technology. Also this utility had decided against such a solution several years ago because of the related cost, however with new technologies the costs have come down and they decided to start out with monitoring 30 transformers and to expand to the rest of the transformer fleet at a later date.

Business Case Quantifies Benefits of Enhanced Asset Management

The Business Case quantified the utility's cash flow generated by the transformer fleet. For a valid answer the current cash flow was compared with the projected cash flow due to the new online monitoring solution. Decision-makers were not only interested in cost and benefit, but especially in the risks that had been misjudged so badly.

The first step on answering these questions is to build an Influence Map (FIGURE 1) to help define what aspects solid asset management needs to consider, and how changes in the maintenance strategy would influence the business outcome. They were especially interested in reducing the gas induced failures in their transformer as it was the biggest cause in their fleet's failures over the last years.

The cost of a transformer's total failure is immense, the bill may be as high as €11 million when oil has leaked from the transformer. It either requires a costly re-build or investment in an entirely new transformer. With even a minor disruption in operation there will also be revenue losses and penalties from the down-time period. In addition, the collateral damages to the infrastructure might call for further repair expenses or at the very least, require excessive clean-up time and the utility wanted these real-life scenarios and their probabilities to be covered in the Total Cost of Ownership (TCO) analysis.

In order to avoid comparing apples and pears, both scenarios (old maintenance solution vs. online DGA) are structured in the same way. The Influence Map serves as the basis for the financial model so the scenarios become comparable by quantifying the

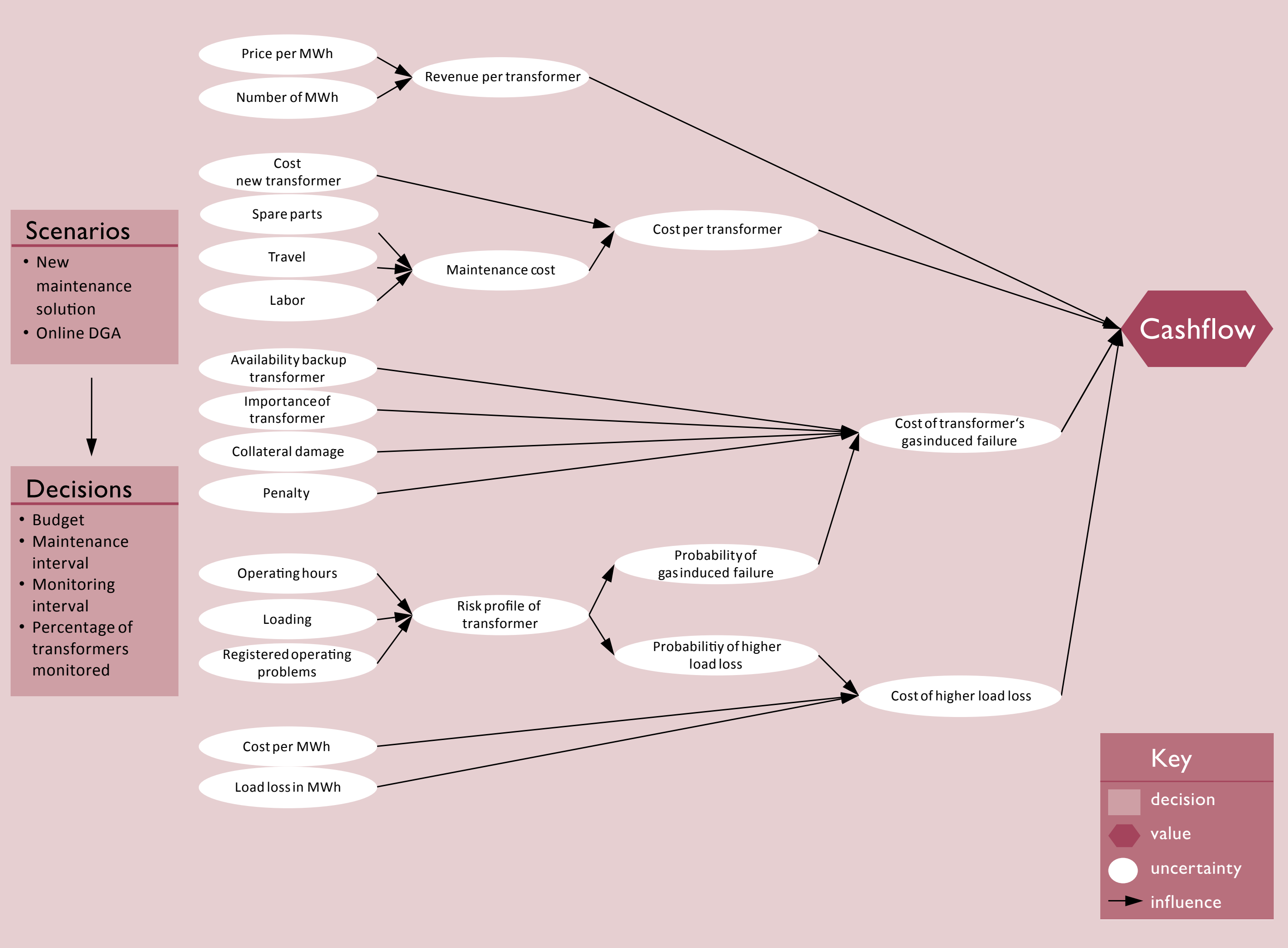

FIGURE 1. *The Influence Map covers all elements that are relevant for the asset management of a utility's transformer fleet. Source: Solution Matrix.*

cash flow. The scenarios differ by the data that is assessed. While uncertainties represent uncontrollable values, the decisions are the controllable aspects of an investment. Decisions concern budget, maintenance intervals, monitoring intervals and percentage of transformers monitored. In cases where data for the previous years is unsuitable or unavailable, data for the uncertainties is collected interviewing experts to get the relevant numbers in interval estimates for the coming 30 years. The advantage of operating with intervals that cover the minimum, most likely, and maximum values is that they replace simple point estimates that are definitely wrong. A financial model featuring these three values can then be validated by a risk and sensitivity analysis.

The Influence Map shows all relevant impacts on the cash flow that decision-makers need to consider. The biggest influences are last in the stream: revenue and cost per transformer, cost of transformer's gas induced failure and cost of higher load losses. These uncertainties cannot be determined en bloc, they arise from the gathering of several points of uncertainty. The risk profile of a transformer, which determines the susceptibility for higher performance loss or even a complete failure, can initially be determined by its operating time. However, other uncertainties like loading and registered operating problems may have a profound effect on the outcome and must be taken into account as well. » »

The actual cost of transformer failure is determined by four uncertainties that form the underpinning for calculating the possible costs of a total transformer failure: availability of a backup transformer, the importance of the transformer within the grid, collateral damages, and penalties for failing to meet contractual obligations. The maintenance costs are comprised of the cost of spare parts, labour and travel expenses. The Influence Map therefore gives an overall idea of what asset management of the fleet needs to consider.

Not Any Online DGA Would Do

Looking at the new online DGA the utility made several decisions about what to look for, they wanted a solution that guarantees basic monitoring, but which would be scalable later on. Solid results at low cost was the most important criteria, but the option of adding even more specific data later on should not be impossible either. Not only the power transformer itself should be monitored but also crucial ancillary equipment such as load tap changers (LTC). Furthermore, they did not want to use instruments that needed to be sent back to the factory in order to be calibrated.

The power transformer itself is monitored by measuring three gases (hydrogen, carbon monoxide, acetylene) and moisture. These gases in the transformer insulating indicate faults, acetylene indicates arcing and low intensity discharge and carbon monoxide indicates cellular degradation of paper insulation. The online monitoring with its constant output of data makes it possible to pay attention to trends that are far more reliable than one point estimates which might be an unrepresentative extreme. Later on the utility would be able to scale their monitoring onto analyzing six gases more such as carbon dioxide or methane.

For monitoring the LTC two indicators are analyzed, acetylene and ethylene. It is essential to know of these gases as the LTC has the potential to destroy the entire transformer worth several million €, but even replacing only the LTC for a high power transformer which costs €100,000 is a risk to be avoided.

With the data provided by online DGA the cash flow was very different. Labor cost was lower; the probability of gas-induced

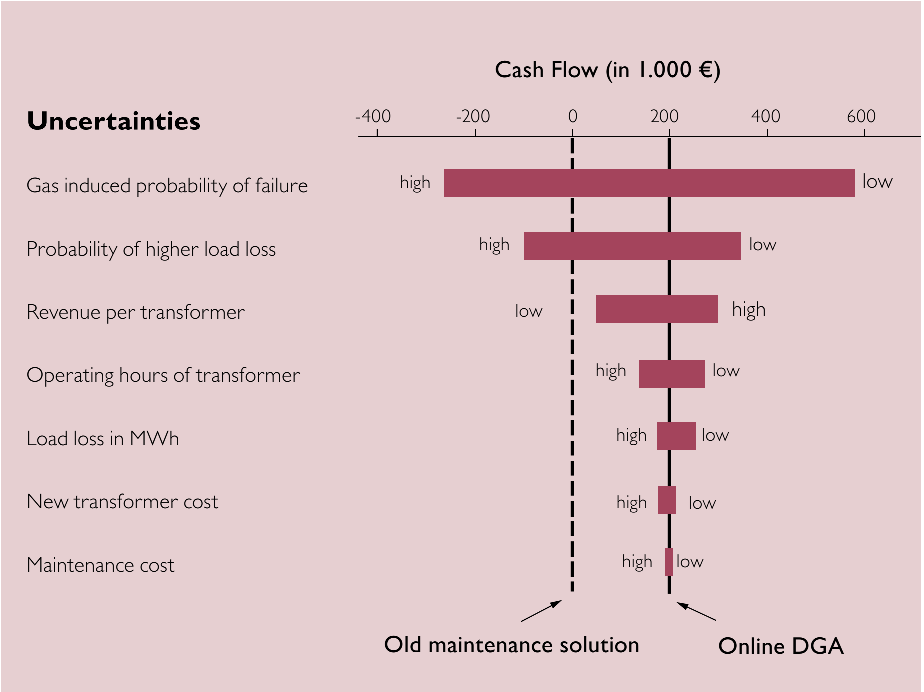

FIGURE 2. *The tornado diagram is a tool in the sensitivity analysis which prioritizes risk factors due to their quantification. Source: Solution Matrix.*

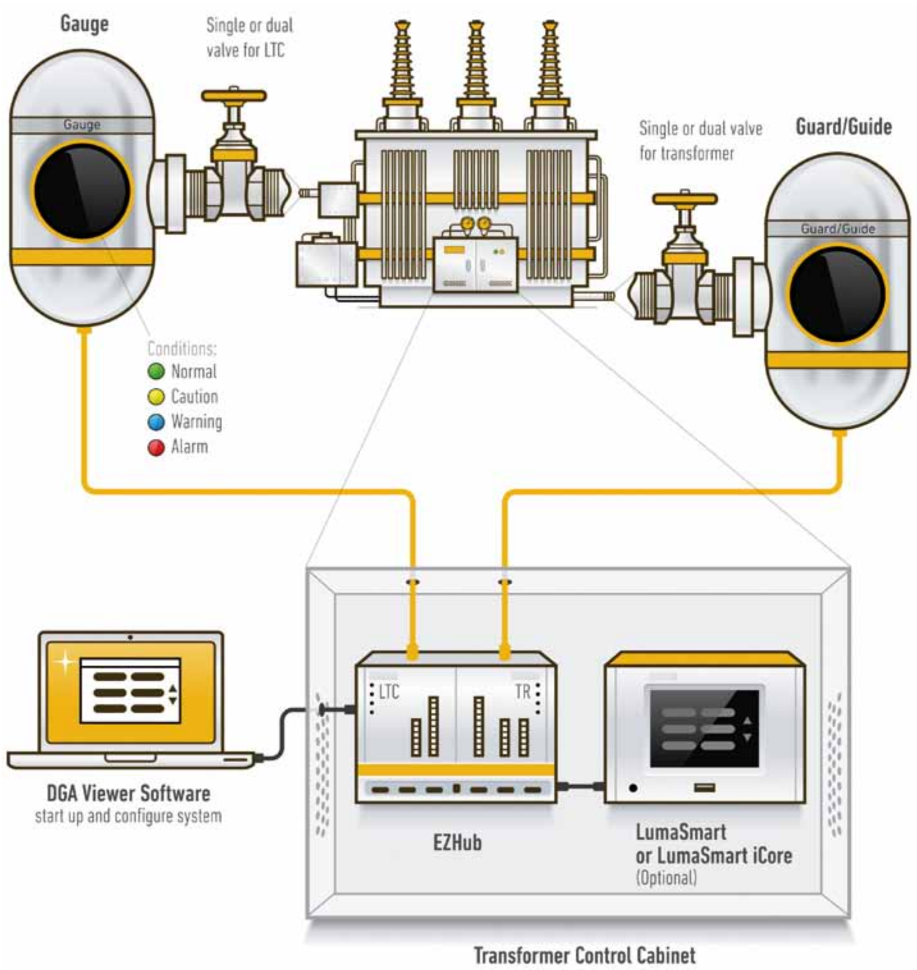

FIGURE 3. *Smart DGA System diagram. Source: LumaSense Technologies.*

failure was heavily reduced as well as the probability of higher load loss. Reliable actions at an early point had a massive effect on increasing the cash flow as indicated in the tornado diagram in FIGURE 2.

Minimizing Gas-Induced Probability of Failure Is Key

The calculated results of the financial model are validated by risk and sensitivity analysis. One of the strengths of such a Business Case is that it quantifies the impact of risk to the end result, in the case of transformers it is the probability of failure specifically caused by the gas-induced failures. The tornado diagram is one of the tools and it delivers an overview of the largest risk factors and their impact to the end result. It is hardly surprising that the occurrence probability of the gas-induced transformer's total failure induces the highest risk. "Probability of a higher load loss" and "revenue per transformer" have lower but still significant impact to the end result. Maintenance costs, despite the investment into the new online monitoring solution, turned out to be the smallest risk factor.

When considering a new maintenance solution the discussions tend to focus on the investment costs, TCO, and implementation details. The tornado diagram will end these discussions with clear answers as it highlights the areas of biggest impact, the best way for a more efficient asset management is minimizing the risk of failure of the transformer fleet. ■

» FURTHER information
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