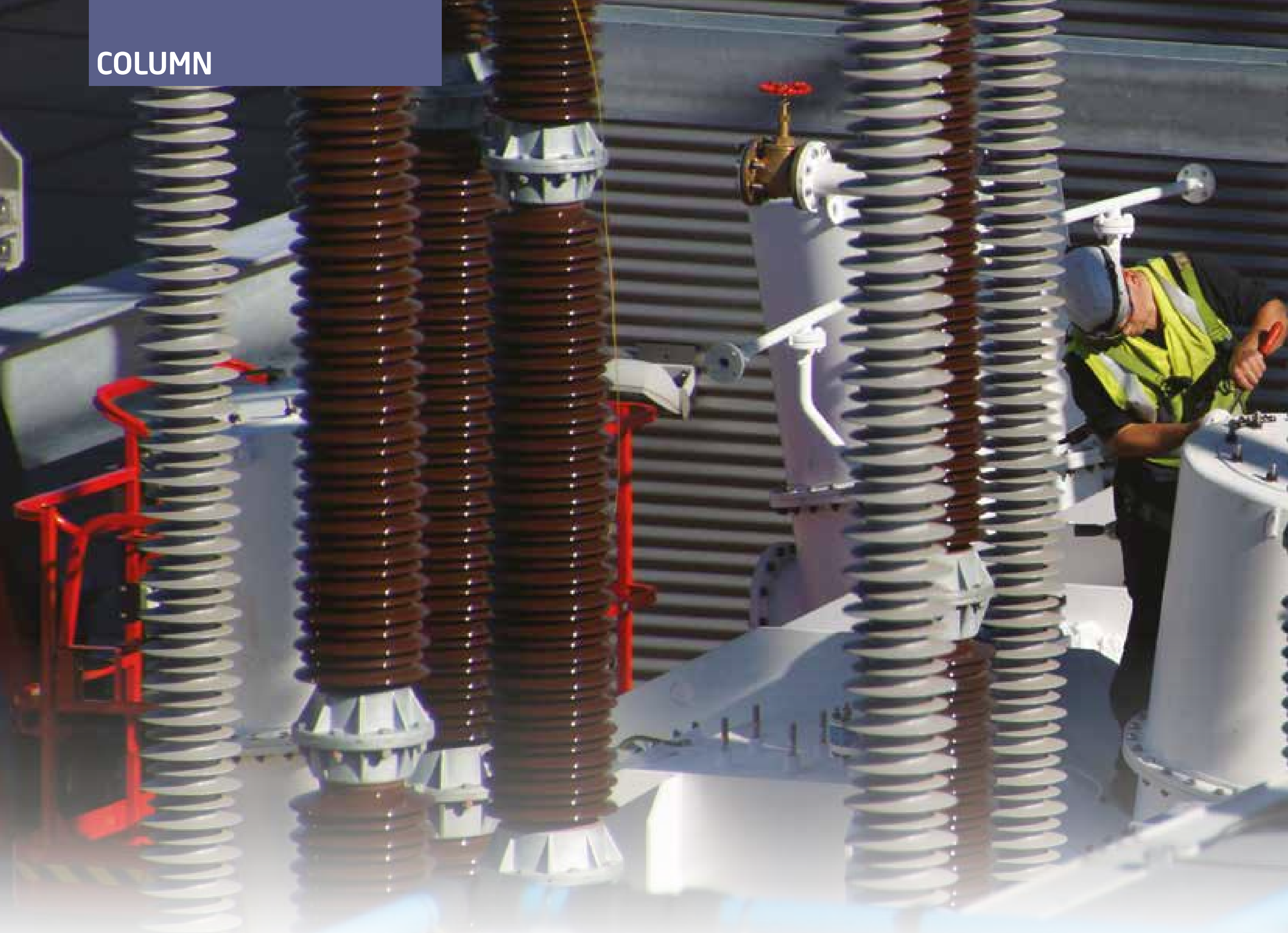


Power transformer asset management

ABSTRACT

In 2014, the ISO 55000 standard on asset management was issued, providing an internationally recognized framework for asset management that utilities can adopt to enhance the asset performance while controlling the risks at acceptable costs. This standard is, deliberately, made applicable to different kinds of organizations and assets, hence it does not elaborate on the management of specific assets in specific organizations. As a result, it is the utility's responsibility to translate this framework into technical asset management processes along the lifecycle of assets. This was recognized in the 2015 IEC White Paper on *Strategic asset management of power networks*, which has eventually resulted in the formation of a new IEC Technical Committee (TC 123) dealing with the management of network assets in power systems. In this contribution, I will focus on power transformers and discuss the difference between asset management and managing assets. Further, I will explore options of introducing something like *power transformer asset management*, which, on the one hand, needs to be in compliance with ISO 55000, but on the other, needs to provide more detailed guidance to asset managers and operators.

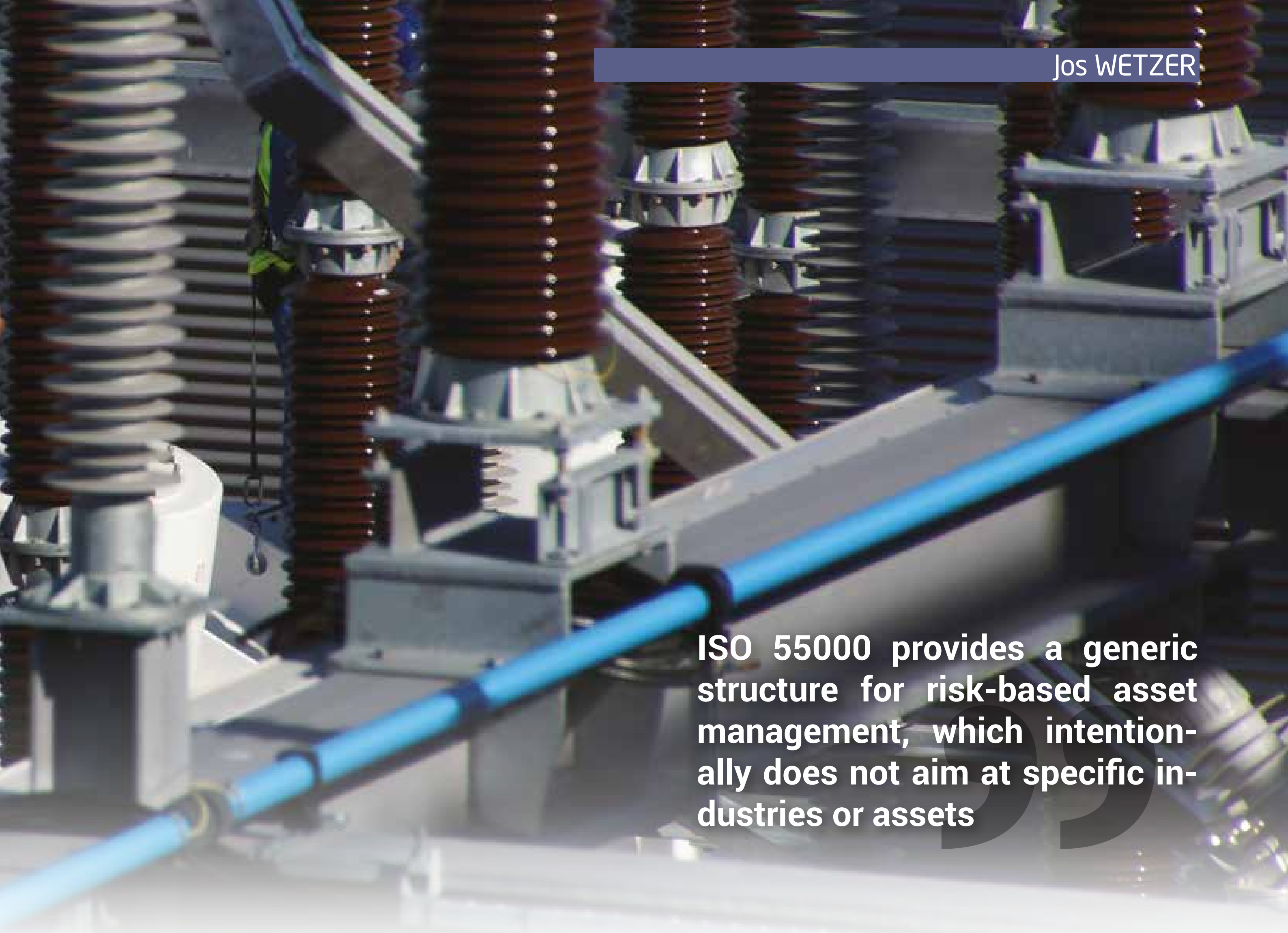
KEYWORDS

asset management, ISO 55000, lifecycle

1. Introduction

Today's world increasingly depends on electrical energy. Small and large consumers have become more vulnerable in case of outages but are, at the same time, more aware of their energy dependence, and more critical towards energy suppliers. Driven by the need for efficiency, risk control and transparency, we have seen the emergence of asset management standardization. With the introduction of PAS 55 in 2004 [1], its revision in 2008 [2], and the launch of ISO 55000 in 2014 [3], there is now an internationally recognized framework for asset management that utilities can adopt to enhance the asset performance while controlling the risks at acceptable costs.

In the electrical power system, power transformers have a crucial function. Primarily, they are needed for voltage regula-



ISO 55000 provides a generic structure for risk-based asset management, which intentionally does not aim at specific industries or assets

tion. Next to that, they help increase network stability. As a whole, the transformer population represents a significant monetary value. Moreover, improper management, design and operation of power transformers may lead to reliability issues and failures, significant costs and service interruptions, capacity bottlenecks and congestion, and stability issues.

The question addressed in this contribution is: How can asset management standards be better utilized for optimized transformer management and controlled performance? Can we define something like *power transformer asset management?* And if so, what would that look like?

2. What is asset management?

The term asset management is commonly used for organizations dealing with financial or physical assets, an asset being defined as anything (an item, thing or entity) that has a potential or actual value to an organization. In the context of this contribution, assets are considered to be physical electrical network assets such as transformers, circuit breakers, cable, lines and the like.

The asset management specification PAS 55 and the standard ISO 55000 have been adopted by several industries, among which the power network industry. The standard is generic in the sense that it is applicable to different kinds of organizations, each having their own definition of assets. Asset management is defined as the coordinated activity of an organization to realize value from assets.

A central part of the asset management standard is focused on how to guarantee performance while controlling risks at acceptable costs. Essentially, the standard is a structured approach to assure stakeholders that the various activities are aiming at creating value to the company. As the standard is, deliberately, made applicable to different kinds of organizations and assets, it does not elaborate on the management of specific assets in specific organizations.

Although many power utilities are certified according to the ISO 55000 series, and the standard provides a valuable framework for an asset management system, policy, risk approach and decision methodology, utilities are struggling to translate this framework into technical asset management processes along the lifecycle of assets.

3. *Managing assets versus asset management*

In the 2015 IEC White Paper on *Strategic asset management of power networks* [4] it was recognized that, whilst standards such as the ISO 55000 series provide guidance on best-practice asset management processes, they do not provide the industry-specific guidance that is needed given the operational methods and challenges of the electricity transmission and distribu-

Transformer asset management needs to comply with ISO 55000, but also provide more detailed guidance to asset managers and operators

> **Ensuring the quality and controlling the associated risks involves management of the complete power transformer lifecycle**

tion industry. As a consequence, network businesses around the world use different performance metrics, making it difficult to benchmark across organizations. Also, there is a lack of consensus as to what is best practice regarding lifecycle management, health and risk procedures, prioritization or performance optimization.

This has resulted in the formation of a new IEC Technical Committee (TC 123) on the management of network assets in power systems, which kicked off in February of 2018. This committee is installed to deliver standardization regarding methods and guidelines for the coordinated lifetime management of network assets in power systems, in order to support good asset management.

Electricity networks around the world vary significantly in their operations, performance standards and regulatory regimes. Therefore, standards should not be overly prescriptive, but should provide network businesses with a range of well-defined options and allow them to choose the ones that best match their own circumstances and requirements. This could cover areas such as asset inspection and diagnosis, fault measurement and reporting, common degradation and failure models, remedial actions, lifetime estimation, lifecycle costing, health indexing, prioritization methods and performance indices.

Summarizing, one might say that *asset management* is concerned with a business management system focused on how the organization and processes best serve the value creation to the stakeholders, whereas *managing assets* is translating that to the underlying, industry-specific, lifecycle processes.

As an example, an *asset management* standard may prescribe a process to arrive at a replacement strategy (or any other decision) by a sequence of steps (*what* to do):

- Assess the risk, by evaluating the probability and the impact of failure;
- Use a risk framework (e.g. a risk matrix) and the company's risk appetite to establish the urgency;
- Evaluate the mitigating options, compare the expected results, and create the portfolio;
- Prioritize and manage the portfolio.

A *managing assets* standard would provide guidance on *how* to do that for a specific type of asset in a specific type of industry (for example, a power transformer in an electrical power network):

- How to assess the probability of failure (e.g. by inspections, monitoring, modeling, etc.);
- How to assess the asset-specific impact (on safety, reliability, availability, costs, etc.);
- How to define asset-specific mitigating measures

4. Power transformer asset management

When looking at the sheer definition of asset management (creating value for stakeholders), one could argue there is no such thing as transformer asset management, because focusing on one type of asset leads to sub-optimization when not taking into account the surrounding grid and asset management system. However, it is very well possible to focus on the underlying asset specific processes that support the value creation.

Some typical elements of an asset management system are shown in Figure 1. The elements are generic, and not specific for any sector or any asset within a sector.

When applying the asset management philosophy to a specific sector (electrical power networks) and focus on a specific asset (the power transformer), we can address transformer specific concerns and define transformer specific solutions.

4.1 Transformer related concerns

As a whole, the transformer population represents a significant monetary value. Moreover, improper management, design and operation of power transformers may lead to reliability issues and failures, significant costs and service interruptions, capacity bottlenecks and congestion, and stability issues. As a result one may define transformer related risks and risk-based asset management solutions.

One of the particular concerns associated with network power transformers, which is also recognized in the 2015 IEC White Paper, is the age distribution. Many transformers are approaching or exceeding the expected technical lifetime, thereby introducing an increased risk of failure. Apart from ageing, other concerns may include safety hazards (explosion, fire), environmental issues (oil spill), power losses, obsoleteness and spare parts, and the lack of knowledgeable and competent manpower.

5. Power transformer lifecycle management

Ensuring the quality of power transformers, and controlling the associated risk, involves the complete power transformer lifecycle. This lifecycle starts with identifying the needs regarding future transformers, and ends with the disposal of transformers. Figure 2 gives an overview of the different lifecycle phases, and the relevant asset management processes in the different phases.

Each lifecycle phase has its own transformer specific asset management challenges and processes. Together, they can be incorporated in an asset specific management system, thereby following the generic rules as postulated in the ISO 55000 standard. Based on the power transformer lifecycle, one may discuss and define the key ingredients of power transformer asset management.

- ISO 55000 auditing & certification
- Business process improvement
- Technical process improvement
- Decision making methodologies
- Investment portfolio
- Operational budgeting
- Data quality management
- Risk management

- Incident response
- Business case development
- Technical quality assurance
- Process quality assurance
- Competence development
- Technical training
- Software development
- Communication

Figure 1. Typical elements of an asset management system

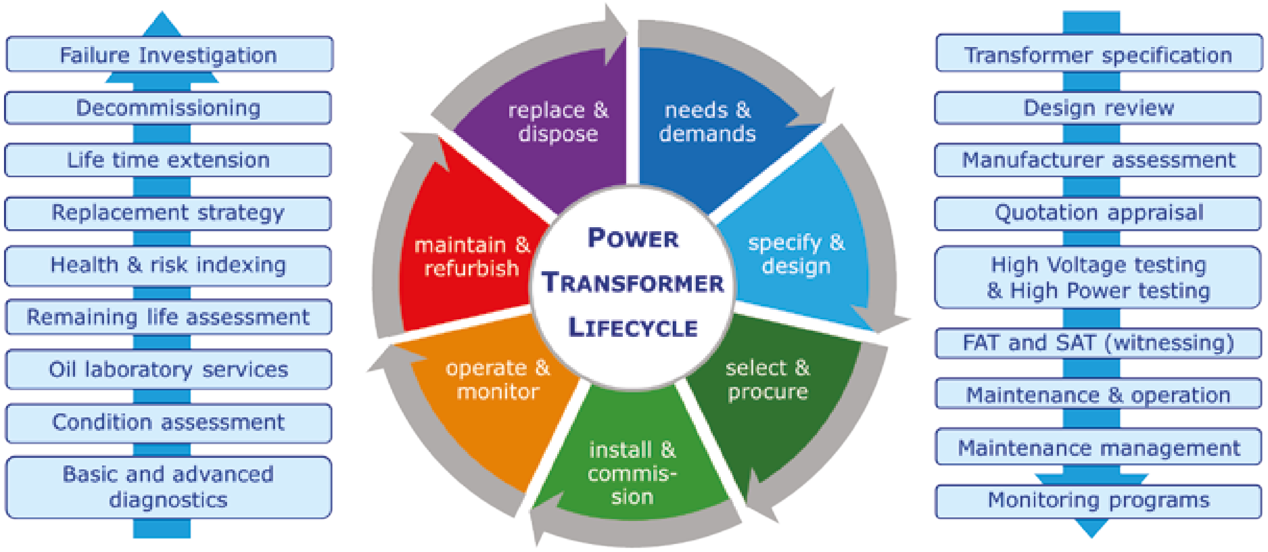


Figure 2. Overview of the lifecycle phases, with relevant asset management processes

Due to the low number of failures in the past, utilities tend to postpone replacement, often however, without having a solid understanding of the associated risks

5.1 Needs and demands

In this phase of the lifecycle, grid performance as well as present and future developments and requirements are analyzed, based on external growth scenarios, past performance and grid characteristics such as the age distribution and asset variety. The aim is to identify the demands for the future grid in terms of expansion, reinforcement or replacement. In this phase also, the transformer requirements are defined and aligned with the overall grid requirements. In modern asset management, the identified needs and demands are then prioritized based on a risk evaluation.

5.2 Specify and design

Once the requirements are defined, the transformer can be specified in terms of voltage ratio and power. However, the asset management system may impose many other transformer requirements based on business values such as safety, environment and costs. A specification may include functional, technical and project specifications, standards to comply with, tests to be performed, maintainability and service requirements, commercial conditions, and environmental and sustainability requirements [5]. Based on the specification, a manufacturer will propose to either design a transformer or select an existing design that fulfills the criteria, and define the surrounding tests, services and conditions.

5.3 Select and procure

In the selection and procurement phase, the user needs to gain the confidence that the candidate transformer fulfills the requirements. If the specification is made SMART, it will contain checkpoints for verification, for example in the form of design review, type test reports or factory acceptance tests, manufacturer quality assessment, the way in which the transformers will be installed and commissioned, and the like. An important part is the quality assurance of the goods delivered.

5.4 Install and commission

Once delivered, the transformers will be installed, usually as part of a project. Installation may be executed by own personnel or by contractors. In either case, a proper quality assurance is essential. The quality assurance involves, next to the actual installation, also the competence of personnel, the procedures and tools used and, finally, the commissioning.

5.5 Operate and monitor

Once in operation, the operating conditions and the performance need to be monitored and controlled. Operating guidelines need to reflect to capabilities, operating margins and limitations of the transformers in order to prevent overloading, early aging, excessive maintenance and failure.

5.6 Maintain and refurbish

The maintenance process aims at keeping the operating condition of the transformers in good shape for as long as economically feasible, whilst controlling the associated risks. A crucial choice that needs to be made is whether to apply corrective, periodic or condition-based maintenance. In modern asset management systems, this is a risk-based decision: the choice of maintenance type (commonly: the right mix of maintenance types) depends on the risk involved. This may be governed by the number of customers connected, the amount of power involved, strategic customers, identified safety, environmental or congestion hazards, and so on. Once the mix of maintenance types is chosen, one needs to define the frequencies, activities, inspection items, measuring tools, knowledge rules and assessment criteria, in accordance with best practice (see for example [6]).
Often, manufacturer recommendations form the basis of the maintenance program, which is understandable from a warrantee perspective. In addition, one may identify the most prominent failure modes and mitigation options and, for example, introduce monitoring techniques for the high risk transformers.
When the transformers get older, a midlife refurbishment (revision lifetime extension) may be considered. Also, this refurbishment may be performed periodically or

In a modern asset management system, risk-based decisions govern the maintenance programs, as well as the prioritization of replacement

condition based. Just like for maintenance, in modern asset management this is a risk-based decision.
However, for both maintenance and refurbishment decisions, other aspects also play an important role, such as the future of the (smart?) grid and the availability of competent personnel, spare parts and service.
For maintenance and refurbishment, risk-based prioritization is important in order to at least mitigate the most important risks, and to postpone activities only if the risks are controlled. For this, it is essential that the asset manager has an overall up-to-date overview of the condition of assets and the associated risks in the grid. Preconditions for that are a high-quality asset database, an effective maintenance management system, and tools to select and visualize the most prominent risks (for example by using a health and risk tool [7]).

5.7 Replace and dispose

One possible replacement policy is to replace transformers after the expected technical or economical lifetime. It is well known from practice that many transformers may survive much longer than that. As a result, replacement is usually postponed, often without a thorough analysis of the risks. This has led to the situation that many transformers are approaching or exceeding the expected technical lifetime, without a solid understanding of the associated risk of failure.
Therefore, lifetime estimation techniques are used more and more. These may be based on models, such as the IEC [8] or IEEE [9] loading guide, or on diagnostics that provide an estimation of the insulating paper degradation from measured compounds in the oil [10]. Modern health and risk indexing tools often involve lifetime estimation algorithms.
Apart from ageing, other concerns may lead to transformer replacement. These may include safety hazards, environmental issues, power losses, obsoleteness and spare parts, and the lack of knowledgeable and competent manpower.
Once a transformer is disposed of, it may still fulfil a function. To start with, it may provide spare parts for transformers that are still in operation, especially for older models that are no longer being manufactured. Further, a post mortem analysis may provide useful feedback on aging mechanisms, and on the validity of aging models used.
Finally, it is important that disposal is performed such that it obeys environmental and sustainability demands dictated by the company environmental policies.

Bibliography

[1] PAS55 2004, BSI, 2004 (PAS 55-1: Specification for the optimized management of physical infrastructure assets; PAS 55-2: Guidelines for the application of PAS 55-1)

[2] PAS55 2008, BSI, 2008 (PAS 55-1: Specification for the optimized management of physical assets; PAS 55-2: Guidelines for the application of PAS 55-1)

[3] ISO 55000 series on Asset Management, 2014 (ISO 55000: Overview Principles and Terminology; ISO 55001: Management Systems Requirements; ISO 55002: Guidelines for the application of Management System Requirements)

[4] *Strategic asset management of power networks*, IEC White Paper, 2015

[5] J.M. Wetzer, *Power transformer lifecycle: Transformer specification and sustainability*, Transformers Magazine, Volume 4, Issue 1, 2017

[6] CIGRÉ Technical Brochure 445, *Guide for Transformer Maintenance,* WG A2.34, 2011

[7] J.M. Wetzer, *Transformer health and risk indexing: Transforming asset data into decision support information*, Transformers Magazine, Volume 5, Issue 2, 2018

[8] IEC standard 60076-7:2018, *Power transformers - Part 7: Loading guide for mineral-oil-immersed power transformers*, IEC, 2018

[9] IEEE Standard C57.91-2011, *IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators,* IEEE, 2011

[10] CIGRÉ Technical Brochure 393, *Thermal Performance of Power Transformers*, WG A2.24, 2009

Author

Dr. Jos Wetzer from the Netherlands is senior principal consultant “Asset Management” with DNV GL Energy, stationed in Arnhem, The Netherlands. He obtained a M.Sc. degree in Electrical Engineering (cum laude) and a Ph.D. degree in Technical Sciences, both from the Eindhoven University of Technology. After obtaining his Ph.D. degree he worked as an associate professor at the Eindhoven University of Technology for 14 years. His activities included research, education and consultancy in the field of High-Voltage Engineering and EMC. In 1998 he joined KEMA (now DNV GL) as a senior consultant, in the field of condition assessment, asset management and EMC. From 2001 to 2006 he held a management position, and from 2006 on he has been active as a (senior) principal consultant, and has served numerous clients in Europe, North America, the Middle East and Asia Pacific on asset management issues. From 2004 to 2007 he also held a position as a part-time professor at the Eindhoven University of Technology in the Netherlands, engaged in Asset Management of Electrical Infrastructures. His expertise includes asset and maintenance management, condition assessment and diagnostics, dielectrics and electrical insulation, electromagnetic fields and EMC. He has published over 150 scientific and professional publications.