# THE RELEVANCE OF QUALITY DATA MANAGEMENT FOR CONDITION BASED RISK MANAGEMENT

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## ABSTRACT

*The electricity industry is experiencing an intensive change due to the new energy market structure and innovation technologies. This, together with latest safety and environmental policies, has a strong impact on how asset intensive businesses within the electricity sector have to deal with asset deterioration and the subsequent modernisation and life extension strategies.*
*This becomes extremely relevant for the UK electricity market, considering the age of the UK´s transmission and distribution network.*
*Therefore, it is necessary to review current policies and develop modern asset management strategies derived from real condition based risk analysis and robust data management processes, in order to implement effective interventions in the ageing assets.*
*This paper presents the business case for the development of these modern asset management techniques, and shows the case study of a new Scottish Power´s risk management project for the most relevant assets in the network: power transformers.*

## INTRODUCTION

The electricity scenario has suffered big changes in recent years, and the linear layout of the electricity supply chain has evolved to a more complex structure, with many new components in place: small scale renewables, different forms of energy storage, electric vehicles, new generation regimes, etc. All these aspects are creating new challenges that have a strong impact in the electricity industry, and that need to be considered in the development of modern asset management and system design strategies.

SP Energy Networks holds one transmission and two distribution licences in the UK, which includes more than 80,000 substations, 60,000km of underground cable and 45,000 km oh OHLs. Most of UK's network was built in the 1950s and 60s, so many of SPEN's assets are in an advance ageing stage. This adds up to a great number of ageing assets that The Company needs to control and manage during their life-cycle.

In addition to this, data collection has grown into a much wider dimension with the introduction of Smart Grids and intelligent devices into the network. Distribution Network Operators now have the challenge of maintaining and monitoring their critical assets efficiently and effectively ensuring reliability and security of supply. However, due to the new real-time data gathering mechanisms, traditional asset management is no longer applicable to handle the additional complexities introduced by these technological advancements. In other words: The volumes of data are becoming too hard for a human to rationalise in real time, and if the network is perceived to be a machine then it is necessary to develop a machine to control it.

So, as a DNO, SP Energy Networks needs to deal with large amounts of collected data coinciding in time with significant uncertainty and new challenges. Therefore, it is necessary to develop new solutions in combination with conventional programs and appropriate data management tools.

The main challenge now is: to turn Big Data Volumes into Smart Business Decisions.

## SUBJECT

In order to face the variety of challenges in the most effective way, a strong asset management strategy is required, which englobes three main points of action:

- Robust and accurate data
- Implementation of modern Asset Management techniques
- Communication across all sectors within the business in decisions related to asset strategies

SP Energy Networks has been working in the development of a strong condition monitoring program based on health and criticality, which generates the deterioration curves assumptions for the assets and the impact of their failure, and therefore defines their asset management strategy and the associated risk.

Historically, these deterioration curves were based only on an age profile which did not include asset parameters, environmental impact or other effects which may slow or accelerate the assets deterioration.

This new model will allow to consider the real condition of each asset and the consequences of that asset's failure.

From the data stored and recorded in all the different systems, the health index of an asset, which goes from 1 to 5, can be obtained. HI 1 represents new assets or those in very good condition, and HI 5 those assets that are end of life. Then the health index is aged to calculate the deterioration curve of that asset and therefore the future expected HI.

In addition, the consequences of that asset failing, also known as criticality, are assessed in terms of: financial impact, safety, environmental impact, number of customers connected, etc.

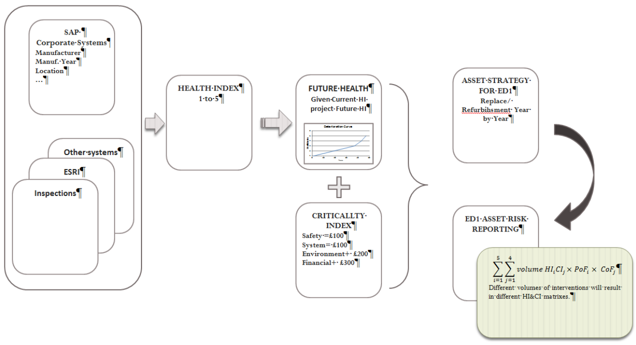



*Fig. 1: Risk score calculation process*

By combining the Health Index with the criticality, the system defines the asset strategy for the following years, and it calculates the risk of any asset or asset group in the future. Different volumes of interventions will result in different HI&CI matrixes and therefore different risk profiles.

The following case study gives a practical view of the development and implementation of this new Risk Management process.

## Case study: Transformers Management System

In the case of the Transformers' fleet, which is one of the most relevant assets in an electricity network, data was split across multiple systems with different owners. Most of the analysis were carried out on an ad-hoc basis and the condition information of the transformers relied heavily on the expertise and personal records of a small number of key staff.

SP Energy Networks began developing a new and improved transformers management system, with the purpose of:

- To simplify data access
- To ensure fully informed, objective and transparent decisions were based on the real condition of the transformers

The first step was to determine all the different departments' information requirements, to make sure the new system captured all the necessary data. Then, all existing data was collected and reviewed, correcting errors and populating any gaps. The cleansed data was then loaded into a single centralised system.

The next step was to develop various calculation and programming processes to define the Health Index of the transformers and, in the end, to extract useful decision support information from the data.

To do so, the already existing Health Index calculation methodology was improved, making a more automated process and redefining the calculation criteria, also including new parameters into the model, through benchmarking of other experienced bodies.

Then, the design and type information was integrated into the final system too, in order to have all the relevant data regarding the transformers stored into one system, and feeding a unique Health Index value.

Finally, the whole system was rolled out to the business.

The new transformers' management system generates an overall Health Index for each asset, based on:

- Internal condition Health Index: generated by an improved calculation process that assesses values and trending of the transformers' historical oil analysis to create a full picture of the assets' internal condition.
- External condition Health Index: based on periodic inspections of the transformer's tank, cooling banks, and main equipment, in order to understand its general external condition, particularly considering oil leakages, corrosion and breaches.
- Design information: this includes commissioning and construction dates, manufacturer details, oil volumes, voltage level, ratings, etc. This also helps SP Energy Networks identify issues associated with a particular manufacturer or construction year.
- Comments from the business: includes all plans and comments, most of which are reported by the operational, maintenance and design departments, to ensure all relevant information is considered in decisions concerning that asset.

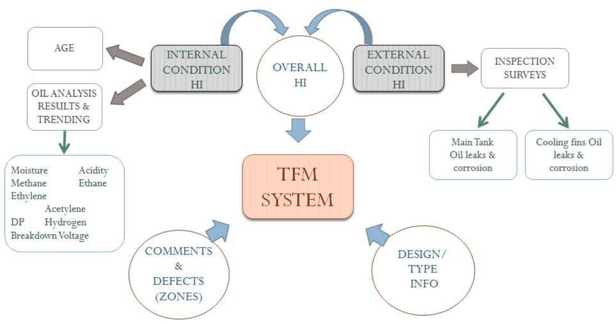



*Fig. 2: Health Index calculation methodology*

**Internal condition assessment methodology**

Mineral insulating oil is mainly composed of three types of hydrocarbon molecules: paraffinic, naphthenic and aromatic. The amount of these components depends on the type of mineral oil used. Also, these hydrocarbons usually include in their molecules other elements such as Nitrogen, Sulphur and Oxygen, which are usually attached to the aromatic structures. A typical molecule of oil could be represented by the figure below:

Mineral insulating oil: $[C_nH_2]_{n+2}$, n=20-40

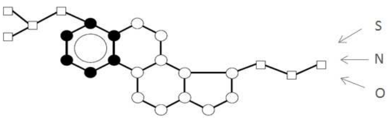



*Fig. 3: Typical mineral oil molecule*

The cellulosic insulation, hence, the paper that covers the windings of the transformer, can be described by this molecule type: $[C_{12}H_{14}O_4(OH)_6]_n$, n=300-750.

Due to the electrical and thermal stresses suffered inside the transformer during its life-cycle, these molecules start degrading, forming different type of components:

- Hydrogen is always present in these faults, as it is the smallest molecule
- Low energy faults will mainly form $H_2$ and methane ($CH_4$), and probably some ethane ($C_2H_6$).
- As the temperature starts increasing, then ethylene ($C_2H_4$) and acetylene ($C_2H_2$) start being generated in higher concentrations. Faults with very high energy content tend to form large amounts of $C_2H_2$. This is the case of Arcing, which is a very concerning type of fault because it can escalate to a transformer failure.
- Pyrolysis of the paper usually generates higher amounts of $CO_2$.

Hence, the gases produced and present in the oil gives a good indication of the performance of the transformers. The tables below give a simple overview of which compounds are created in the different fault conditions:

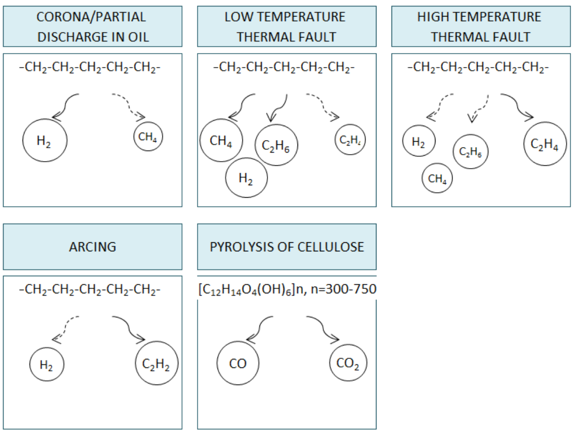



*Fig. 4: Typical gas molecules generated in the different fault types*

In addition to the DGA values, other oil parameters are also measured to understand the internal condition of the transformers:

Acidity: The acidic components in the oil are products of the oxidation processes that occur inside the transformer. Acids and other oxidation products have a negative impact on the oil properties, including its dielectric strength, on the degradation of cellulosic materials, and can cause corrosion of metal parts in a transformer.

The acidity trend of a transformer in service is a good indicator of its ageing rate. Hence, the acidity level is used to estimate the actual internal age of the transformer, and also to determine when the oil should be replaced or reclaimed.

Generally, inhibitors are added to the oil to reduce the oxidation process as much as possible.

Moisture: The water content in the oil influences the Breakdown Voltage (BDV), the solid insulation and their ageing trending. Moisture in the liquid and solid insulation has a significant impact on the actual operating conditions and the lifetime of the transformer.

There are two main sources of water increase in the transformer's insulation: ingress of moisture from the atmosphere and degradation of insulation itself

2-furfuraldehide: Furans analysis has started to be used in the past few years as an indication of the paper degradation. There are still some uncertainties of the precision of this application but it is more and more used to define criticality of the internal condition of the transformer, as the degradation of paper can lead to catastrophic failure.

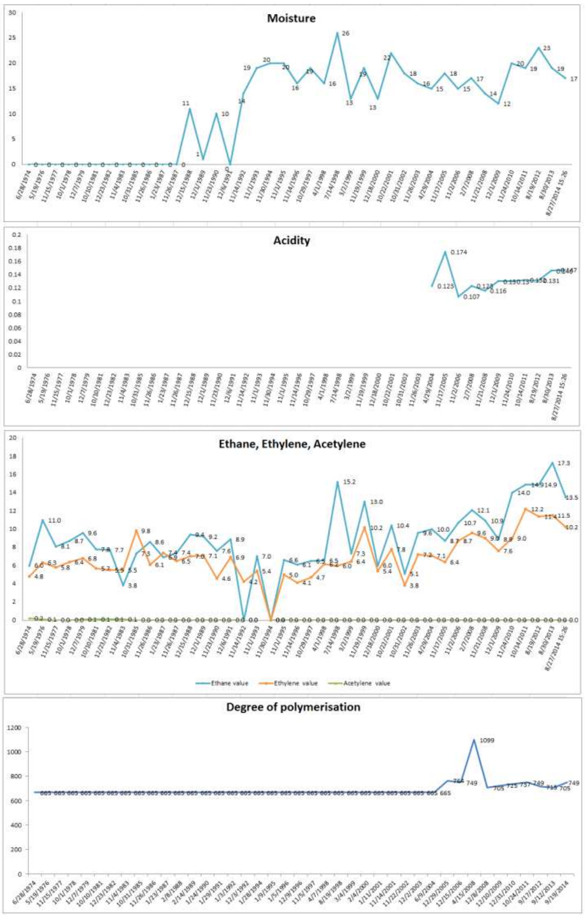
Based on these criteria, the implication of each parameter on the definition of the global internal condition of the transformer was assessed and the HI calculation criteria defined. This is the basis of the Internal Health Index definition of a transformer.

### Transformers Management System

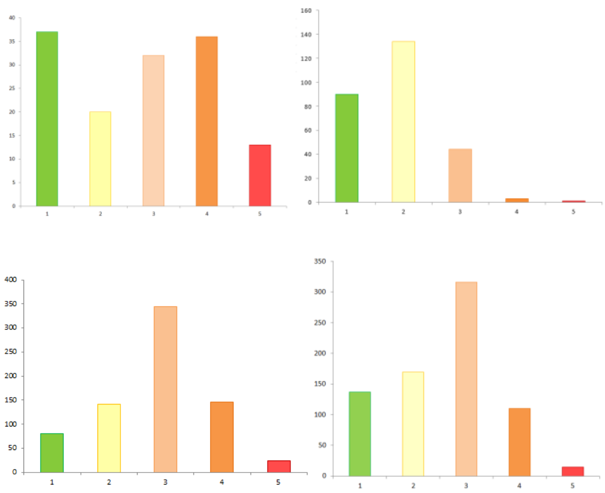
The system is developed in Excel format and is divided in different sections: the information sources and feed-in, the calculation processes and the transformers' condition result sheets.

The following image shows the Summary of all the most relevant information for the whole SP Energy Networks transformers' fleet: In a few seconds it is possible to assess and understand the condition of any transformer installed in the network.

If more detail is required for intensive assessment, the tool also shows the one-to-one trending of the oil historic results that, as explained above, are highly relevant in defining the condition of the transformer.




Finally, the model gives a Heath Index profile for all the transformers' fleet for the three licenses (one of them split in the two main voltage levels for analysis simplification)



## CONCLUSION

The system enables faster and accurate decision-making based on more reliable information, leading to more cost-effective asset management.

Consolidating multiple sources into one centralised system reduces opportunities for error when assessing individual and fleet health. And as the improved Health Index calculation process includes trending, it is easier to analyse asset's deterioration and predict failures, which supports identification and prioritisation of assets for replacement, refurbishment and other life extension programs.

Gathering all the knowledge in a user-friendly format makes it more accessible to different business areas and supports staff with less technical knowledge to make better decisions based on accurate information and criteria.

Before the system was developed, there was no central tool to store all the information related to one transformer, and it was very time-consuming to understand its actual condition. With the transformers management system, it only takes minutes to collate, calculate and obtain the health of the entire fleet.

## REFERENCES

[1] I. E. Davidson, et al., 2005, Utility asset management in the electrical power distribution sector, *IEEE Power Engineering Society Inaugural Conference and Exposition in Africa*, 338-343.

[2] W. Young, 1998, "Transformer life management-condition monitoring", *IEE Colloquium on Transformer Life Management*, 2/1-2/4.

[3] R. Sanghi, 2003, 1998, "Chemistry behind the life of a transformer", *Resonance, Indian Academy of Sciences*, Vol. 8, Issue 6, 17-23.

[3] IEC 60422, Mineral insulating oils in electrical equipment- Supervision and maintenance guidance, Third Ed., 2005-10.

[4] M.Wang, et al., 2002, "Review of Condition Assessment of Power Transformers in Service," *IEEE Electrical Insulation Magazine, IEEE*

[5] IEC White Paper, 2015, Strategic asset management of power networks.

[6] A. S. Alghamdi, et al., 2012, "DGA Interpretation of Oil Filled Transformer Condition Diagnosis", *Transactions on electrical and electronic materials*, Vol. 13, No. 5, pp. 229-232

[7] C. A. Schuman, A. C. Brent, 2005, "Asset life cycle management: towards improving physical asset performance in the process industry", *International Journal of Operations & Production Management*, Vol. 25 Issue 6, 566 – 579.