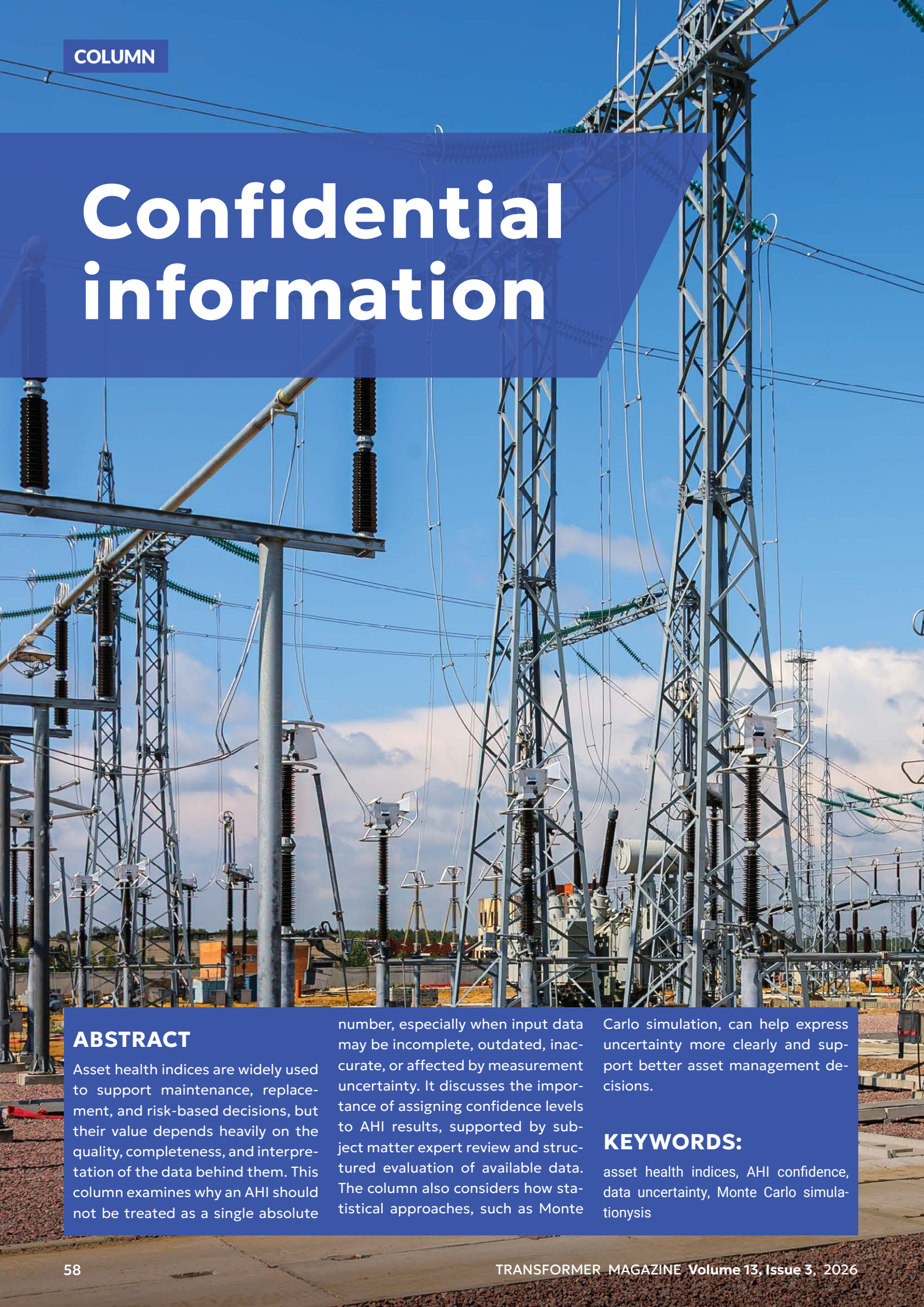
COLUMN

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ABSTRACT

Asset health indices are widely used to support maintenance, replacement, and risk-based decisions, but their value depends heavily on the quality, completeness, and interpretation of the data behind them. This column examines why an AHI should not be treated as a single absolute number, especially when input data may be incomplete, outdated, inaccurate, or affected by measurement uncertainty. It discusses the importance of assigning confidence levels to AHI results, supported by subject matter expert review and structured evaluation of available data. The column also considers how statistical approaches, such as Monte Carlo simulation, can help express uncertainty more clearly and support better asset management decisions.

KEYWORDS:

asset health indices, AHI confidence, data uncertainty, Monte Carlo simulationysis

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Closely related to “closing the loop” is evaluating the data which goes into an individual AHI and identifying how confident we are in any analysis based on that data

In a previous article, “Closing the loop on asset health indices”, we suggested that it is useful feedback to check AHI values against what is actually going on within the asset, basically checking that we’re not misleading ourselves when using an AHI to prioritize and plan maintenance, or planning replacement or retirement, or responding to changes in operational requirements. We discussed several cases where an index value, when compared to actual health/condition, was incorrect. This checking activity is not very common as it can be expensive to take apart an asset after decommissioning to see what state it is really in, and in some cases where the decommissioning has been catastrophic, there may be insufficient pieces of asset left to evaluate successfully.

Closely related to “closing the loop” is evaluating the data which goes into an individual AHI and identifying how confident we are in any analysis based on that data. See Boxes: “What is an AHI” and “AHIs and Condition Monitoring”.

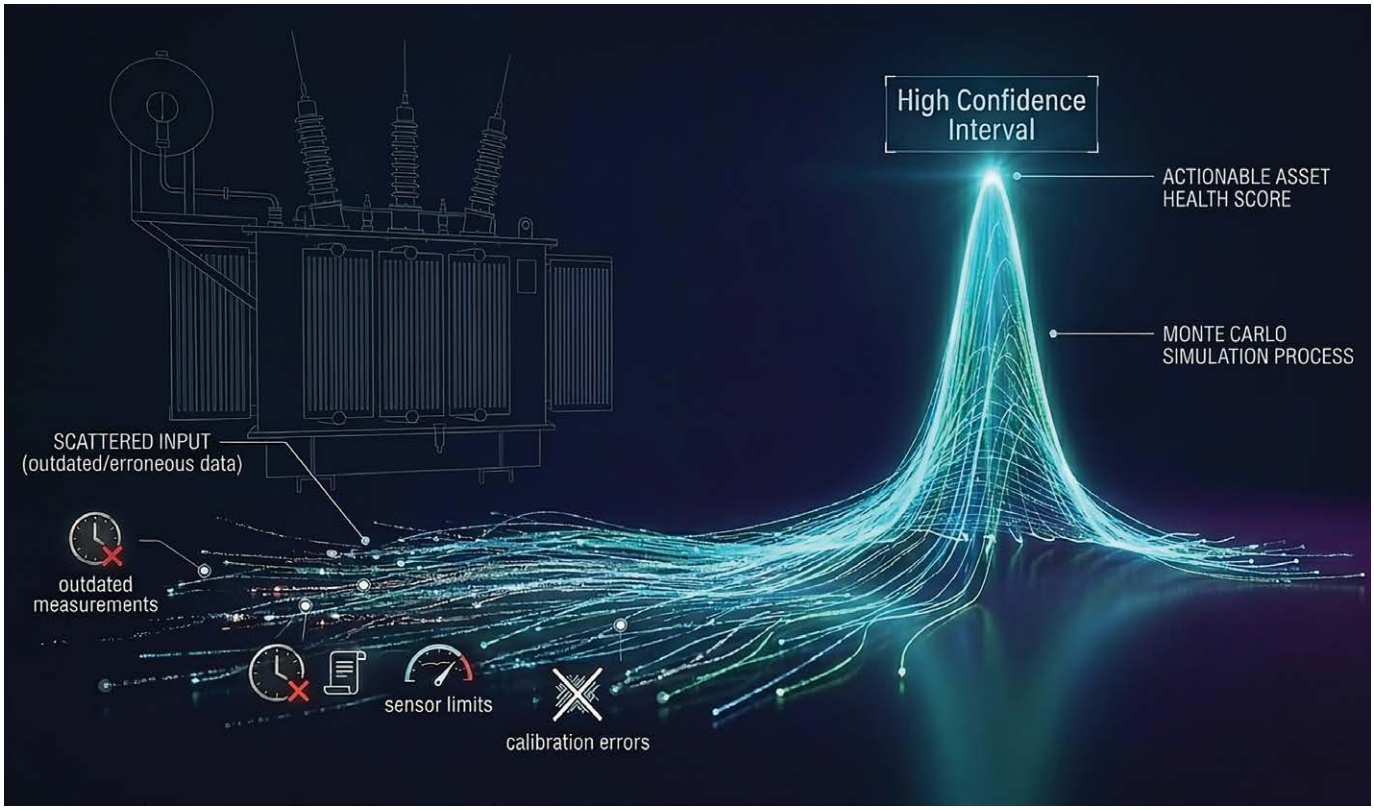
There have been attempts to use an AHI to generate a Probability of Failure (PoF) for a specific asset – this is, in our opinion, the inverse of what is needed. The data feeding the AHI analysis should be analyzed to detect and diagnose possible failure modes and how urgently an intervention is needed, from which we can derive a PoF range appropriate to the urgency. The AHI should then reflect that PoF and urgency.

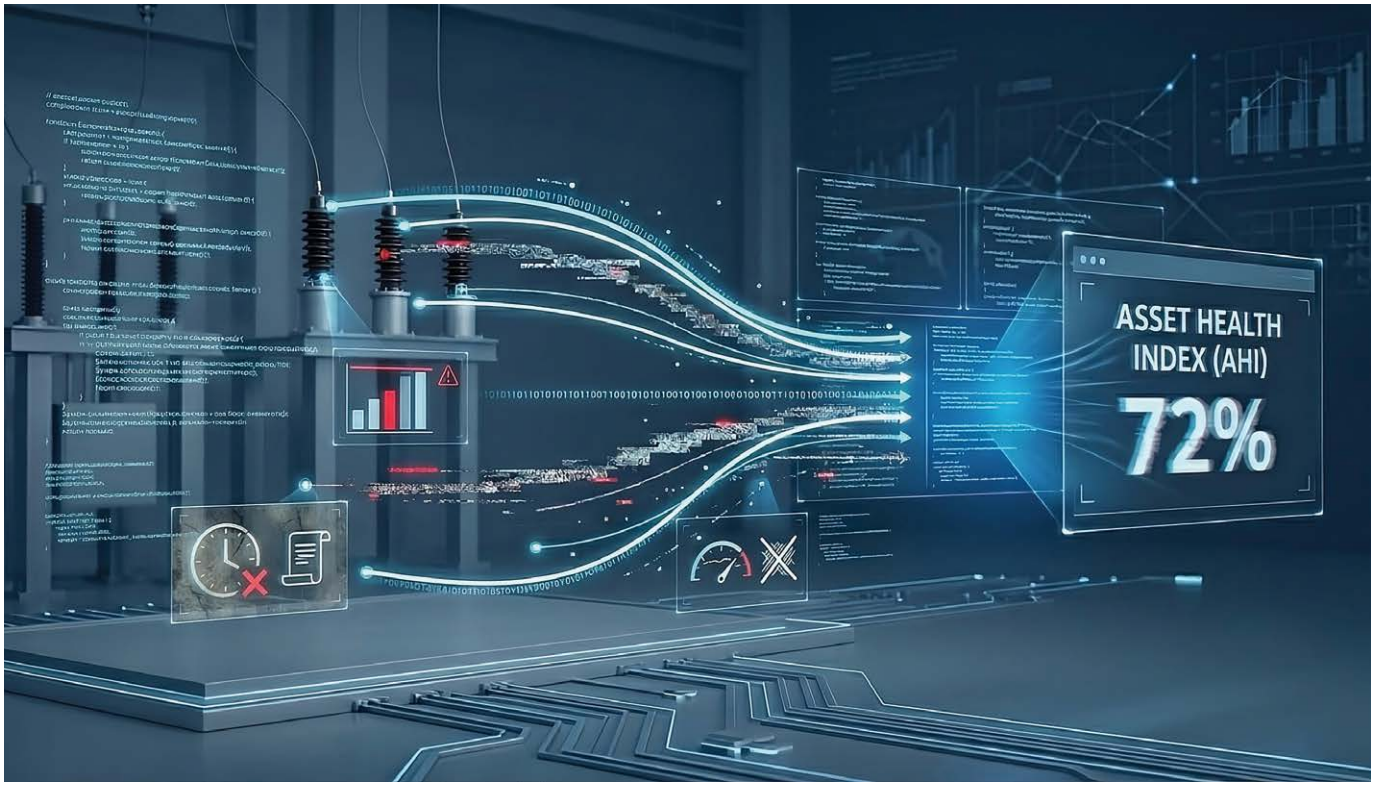
Errors and uncertainty in an AHI can be caused by many sources:

- erroneous raw data where a sensor drifts or a test is performed incorrectly
- invalid or inappropriate algorithms being applied, or inexperienced staff misinterpreting SFRA data, for example
- unexpected changes in wiring, failure of components or sensors
- unexpected operating conditions, or unexpected degassing of transformer oil and/or oil sample contamination
- weighting component analyses so we lose calibration and monotonicity
- transcription errors, such as by entering incorrect nameplate data
- use of old or “stale” data: imagine making decisions about your car tires when the last pressure check was “Good” but 2 years ago…

Errors and uncertainty in an AHI can be caused by many sources

To evaluate the input data requires SME review: what useful data is unavailable, and how reliable is what we do have? This reflects the need of AI applications where AI based digital twin analyses need to be validated, challenged and calibrated by Subject Matter Experts (SMEs). A resulting AHI confidence could be as simple as assigning a category of 1 through 5 where 1 has no data or little data and 5 has ideal and complete data of high precision and accuracy. Such





assignation would be through SME analysis and a "Delphic" Approach which gets feedback from all relevant stakeholders and is reviewed when decisions are being made.

"Confidence" for an AHI:

- reflects SME experience and reflects their view of the available data which may be underpinning a "big consequence" decision such as de-energizing a large transmission transformer
- supports more appropriate decision making where there is uncertainty regarding true asset condition
- supports review of maintenance and inspection frequency and content
- supports contingency overloading
- helps identify where specific asset types and/or designs would have an improved AHI confidence through gathering of specific additional test or assessment data not presently available
- helps identify not only what extra data may be useful, but also whether it would be worth collecting
- supports clear communications with asset managers and spreadsheet folks: what the issues are and how much uncertainty there really is.

Note: confidence in condition monitoring data, specifically, comes from having a good, verified monitor installation where data generated is confirmed as valid and analyses produce expected results which are used to support tactical decisions which are also reviewed.

Diagnostic data is not 100% exact and AHI relies fundamentally on field measurements, which typically have errors due to sensor limits, sampling mistakes, or calibration limitations

Learning from the past through "closed loop analyses" is useful in supporting review and improvement in AHI models for assets overall and their components individually, and brings an element of "realism" to stakeholders who may otherwise think that all AHIs are perfect in every way.

A confidence rating can reflect how much data we have, and how accurate/precise it is relative to some ideal amount of possible data which could be available or collected. But if the asset has a failure mode in operation, and the data supporting that diagnosis is sparse or known to be imprecise, in the first instance we should look at gathering more

AHIs: What is an AHI?

An AHI brings together available data related to asset condition, along with analytic algorithms, to give a score which reflects the condition of the asset. This could be a numeric value, a category, or some other form of encoding the result. A good AHI is monotonic with respect to urgency of intervention based on the result, and calibrated so that all identical indices have the same urgency of intervention. A good AHI could be considered a very coarse digital twin.

An AHI is not a "one-and-done" activity, it needs to be updated frequently, with data and algorithms reviewed by SMEs to ensure they are up to date.

data relating to that specific failure mode to improve confidence in the diagnosis if time permits.

Diagnostic data is not 100% exact and AHI relies fundamentally on field measurements, which typically have errors due to sensor limits, sampling mistakes, or calibration limitations. Therefore, AHI should never be presented as a single, absolute number. Instead, it needs to show our level of confidence in that data. Different statistical methods can be used to achieve that.

Since many data sources are available for a single asset, Monte Carlo simulation (MCS) is a solid tool to handle this. Instead of calculating the AHI using one fixed set of inputs, MCS calculates it thousands of times using a range of possible values based on the known error margins of each data source. The final result is a probability range rather than a single score. If a data source is completely missing, error margin is not just small percent 5% or 10%. Maximum possible range for this missing measurement, from best possible value to worst possible value, is used.

If AHI range is wide, it means our confidence is low, and the final score might be affected by bad data. Conversely, a narrow range means our confidence is high. For example, an AHI is calculated at 75. If MCS shows a 95% confidence interval ranging from 50 to 90, that gap is too wide and indicates more accurate measurements before making major intervention. However, if the interval is narrow, such as 73 to 77, the score is very reliable, and confident enough to prioritize an action.

AHIs and Condition Monitoring

Condition monitoring is tactical, with data being generated in real time and response may be required immediately. Monitoring systems need to be managed from implementation so that the data, interpretation, alert criteria, response plans and reviews are all in place independent of any AHI system. Of course, monitoring data can and should feed into an AHI.

If AHI range is wide, it means our confidence is low, and the final score might be affected by bad data

With all that said, the important thing is to make a start with what is available, generate a confidence value for each AHI, and then look to improve both AHI and Confidence in a continuous process of data collection and analysis review. Starting by doing something means then you can go on and do something else, keeping track of what works well, and what may work less well!

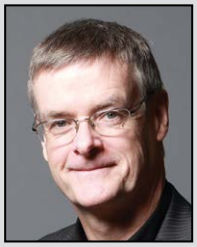
Authors



Dr. Richard Heywood is the Managing Director of Doble PowerTest and VP International Services. He graduated from Surrey University with a PhD in thermal ageing of transformer paper and then worked in the Substations team at National Grid's UK Technology Centre at Leatherhead on transformer issues before joining Doble PowerTest Ltd as Operations Manager in 2002, specialising in high voltage testing and condition assessment of equipment in power stations and substations, specialising in Transformers. He is involved with several CIGRE working groups covering solid insulation, ageing and markers.
He currently manages a team of 50 specialist engineers outside of North America for Doble Engineering. Responsible for managing all aspects of the company financial, environmental, health and safety requirements. Including site assessment of all equipment types, such as Transformers and Generators. Additionally, he managed the delivery of a broad range of other testing and consultancy services for high-voltage substation equipment to clients across the world to compile condition assessment reports to recognise and validate replacement schemes.



Dr. Mohamed Khalil is a Business Development Manager for condition monitoring solutions at Doble Engineering Company. He has more than 18 years of professional experience in transmission substation environments. He holds an M.S. degree in Electrical Engineering and a Doctorate in Reliability Engineering from Politecnico di Milano, Italy. He is an active member of CIGRE and IEEE.



Dr. Tony McGrail of Doble Engineering Company provides condition, criticality, and risk analysis for substation owner/operators. Previously Dr. McGrail spent over 10 years with National Grid in the UK and the US as a Substation Equipment Specialist, with a focus on power transformers, circuit breakers, and integrated condition monitoring. Tony also took on the role of Substation Asset Manager to identify risks and opportunities for investment in an ageing infrastructure. Dr. McGrail is an IET Fellow, past-Chairman of the IET Council, a member of IEEE, ASTM, ISO, CIGRE, and IAM, and a contributor to SFRA and other standards.