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Strategic Approaches to Future Grid Reliability

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SUMMARY

Grid reliability may be seen as a significant driver for investment in the electricity transmission system. However, it behooves us to ensure that the driver is met efficiently and effectively, reflecting the ISO 55000 Asset Management needs for balance in cost, risk and performance in a sustainable manner (1). In a simple strategic overview, we might ask:

- Where are the 'weak spots' in the present system that need to be addressed in terms of condition and capability?
- What will the transmission system assets need to be able to 'do' in future, again, in terms of condition and capability?
- How do we address the present situation and plan to meet future need in a manner which is sustainable? That is : what are our strategies to address the gap between present and future?

There is a need to ensure that we address each question systematically:

- Understand the present condition of a range of assets, their likely longevity, and what can be done to make sure they meet their *nominal* asset life
- Clearly specify assets which can be relied upon to the future, and make sure these are built to appropriate standards, and then tested in the factory and in the field to make sure they meet those standards
- Identify strategies that can be employed to assist in collecting information and decision making regarding asset condition and capability
- Monitor asset performance, as per ISO 55000, to ensure that the operational context of the asset does not produce any unforeseen issues, and we plan for the unexpected

This paper will cover activities which address the three strategic questions. Appropriate investment means that we can justify investment and improve both system reliability not only in terms of 'prevention' of system interruptions, but also in terms of 'cure' after a significant event.

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KEYWORDS
Grid, Reliability, Resilience, Investment, Asset Management, Strategy, Condition, Monitoring, Cost, Risk, Performance, Sustainability

Power Grid & Reliability

Every day, hundreds of millions of people come home and expect the lights to come on when they flip a switch. Those of us familiar with the electric grid understand why in 2000, the National Academy of Engineering voted on the electric transmission system as one of society's greatest inventions of the 20th century (2). From one of the greatest inventions of the century, to the simplicity of turning a switch and having the lights come on every time, there is a lot of effort, including time, money and engineering expertise which must come together to provide the expected level of reliable performance. We do need to have an indication of *expected* levels of service – to define reliability for the customer – so that we can then look at how to meet that in future as the world around us changes.

Climate Change Affect on the Grid

Climate change has led to more severe weather than we have ever seen recorded. Recently, parts of Europe experienced the hottest summer temperatures they had ever seen. The presence of this severe weather can cause extreme damage to an already overloaded grid as cooling systems become less effective. Transformers in particular can be particularly affected, as additional heat also causes transformers to age prematurely by degrading the cellulose based insulation more rapidly.

Quality & Standards

The grid system is already stressed and often operates with overload condition, which means we need to strengthen or harden the grid. However, we need to make sure we are using quality equipment for the improvements required – otherwise we may be forced to repeat 'improvements' on a short timescale, which is not a sustainable approach. To ensure the quality required is achieved, asset owners and operators should look to standards published via industry bodies such as CIGRE and IEEE for guidance in the design and maintenance of the transmission system. For instance, the IEEE loading guide for transformers can be used to identify nodes on the system that may be able to be overloaded to move load around the system, and also identify limits that the transformers can be subjected to for short periods of time. In addition, we need to look at how standards need to evolve: the interoperability of microgrids, for example, using renewables is covered by several standards and guides from both IEEE and IEC (3,4,5). The rate at which these standards need to be reviewed and updated is only likely to increase over time, requiring people who are knowledgeable in both the technical aspects and the environmental influences.

Transmission Backbone

Utilities may have long transmission lines and large fleets of power transformers to support their customers. Many of these lines and transformers are highly loaded or perhaps even overloaded. Furthermore, the age of many units are in excess of original design life and have unclear asset conditions. The end result is possible operational use which brings accelerated ageing and runs transformers much closer to failure.

The problem of loading, and expected transformer life, usually arises when a short term load is applied to a transformer – either as a result of system contingencies or planned outages. The condition of the transformer must be considered before overloading and must be continually monitored during overload. Utilities must have the wherewithal to proactively monitor transformers that has been overloaded and ensure they remain 'Fit for Purpose'.

Data Collection and Knowledge Management

Data becomes a key tool to identifying where the weak spots might be on the transmission grid. Data can be collected from a number of places, including thermal sensors and on line DGA and moisture sensors across a range of transformers which can be used to make sure that the asset is providing its full capability in terms of loading in a safe and reliable manner.

Particular transformers may be seen through simple charts linking load, ambient temperature, calculated hot spot and measured hot spot temperatures. Figure 1 shows some key parameters in terms of managing transformer load using an IEEE or IEC loading guide.

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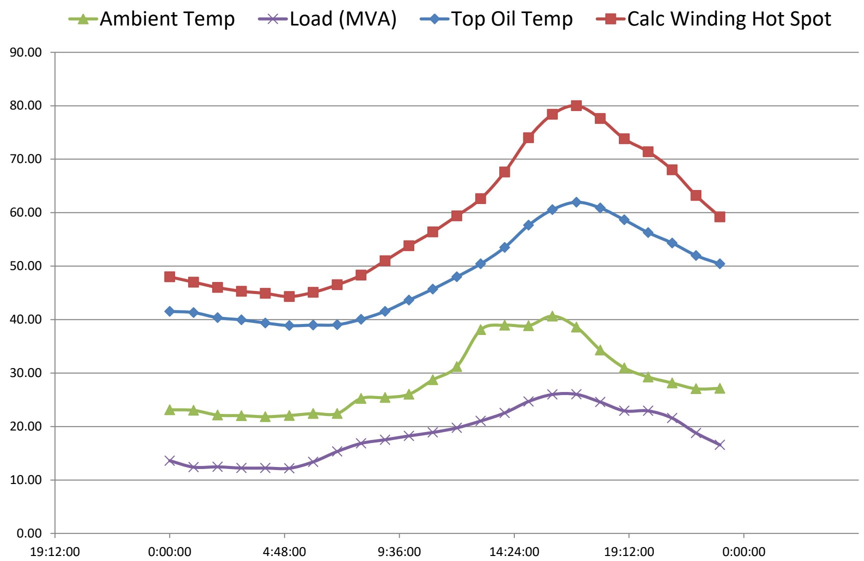

Figure 1 Key Temperature Parameters and Load Recorded for a Daily Cycle

Predictive temperature assessment looks at the present thermal condition of the transformer and predicted loading to give a 24 hour cycle of predicted temperatures, specifically for the hottest spot within the transformer as this is where maximum ageing of insulation will take place. The planned load cycle and predicted ambient temperatures are used to calculate future temperatures – the algorithm acting as a simple but focused 'digital twin' which allows decisions to be made about the asset operation.

In practice, the 'digital twin' loading outputs need to be validated against reality, checking the predicted values against measured values to ensure the model is 'good'. This gives confidence in loss of life calculations – Figure 2 showing that in terms of *per unit* calculations a transformer lost almost two days of insulation life in a 24 hour period.

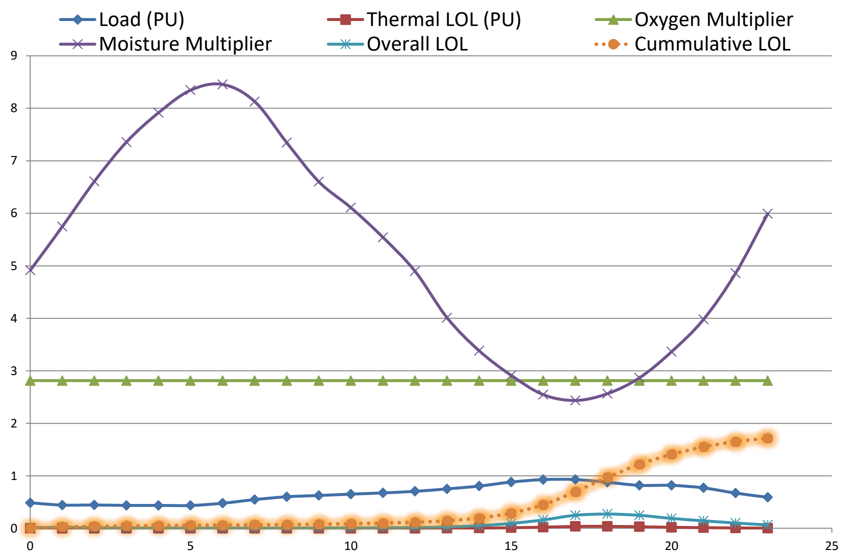

Figure 2 Predicted Loss of Life and Thermal Condition

The feedback between calculated and measured hot spot temperatures provides valuable insight, as strict application of the IEEE loading guide may be too conservative and overestimate real losses.

This asset performance management approach needs to be applied across all grid assets, but with a much longer time frame than 24 hours – and with scenarios far broader than just ambient temperature variation (6).

Prediction

It isn't sufficient just to know the present condition of assets, we need to know how they will perform in future under a variety of possible conditions. In simple terms we need not only to know how close to the cliff edge we are, but also which way we are facing, how fast we are moving, and what the world around us is doing.

Resilience

The more data and information that can be collected and turned into knowledge, the better the transmission grid can be supported and the more reliable it becomes. Utilities are going to greater lengths to understand the performance of their systems, using digital twins to fully model their grid, and simulate historic weather events to determine where they are vulnerable, and what can be done to become more resilient. With appropriate monitoring, elements of the Grid which deteriorate or become vulnerable may be addressed automatically, leading to a more 'self aware' and 'self healing' grid. Application of AI has great promise, but as can be seen with autonomous cars, human oversight is needed as we don't necessarily know everything that may happen.

Conclusions

Climate change is just one environmental factor will have a significant impact on the operation of a reliable electric grid in the near future. It is critical for owners and operators to identify the current weak spots through industry standard methods, recognize what the assets will need to be able to do in terms of the present and the future with regards to condition and capability.

Collecting information in the present and understanding the health of the fleet of assets will allow for a plan to meet future needs, making sure the grid in the future is both reliable and resilient. In summary, strategies needed include:

- Scenario planning of how the world is changing and how those changes affect each asset and each system on the grid in terms of performance need
- gathering data to understand the present condition of the grid and the timescales needed for intervention: whether maintenance, refurbishment, replacement or retirement
- future requirements for a grid system – from a customer reliability perspective, balancing cost, risk and performance in a sustainable manner, building in resilience as a means to recover from events and return to acceptable levels of reliability
- Make plans in a flexible manner to address variations in scenarios

BIBLIOGRAPHY

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[1] ISO 55000 Standard, Asset Management, 2014

[2] American Association Of Engineering Societies. "National Academy Of Engineering Reveals Top Engineering Impacts Of The 20th Century: Electrification Cited As Most Important." ScienceDaily. ScienceDaily, 3 March 2000. <www.sciencedaily.com/releases/2000/03/000303075501.htm>.

[3] IEC TS 62898-1:2017, 'Microgrids - Part 1: Guidelines for microgrid projects planning and specification'

[4] IEEE 2030.7-2017 – 'IEEE Standard for the Specification of Microgrid Controllers'

[5] IEEE 2030.9-2019 – 'IEEE Recommended Practice for the Planning and Design of the Microgrid'

[6] K Elkinson, T McGrail, "Condition Monitoring - Data Driven and Knowledge Based Analyses", 2016 CIGRE Canada Conference