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Asset Management in the Digital Age

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SUMMARY

Between the ongoing development of an International Standards Organization (ISO) Standard for Asset Management, and the continuing push towards implementing a Smart Grid, our business is changing rapidly. When this is coupled with the fact that outages are increasingly more difficult to get, it becomes critical to use available data and analytics to pinpoint which assets are most at risk, and which need the most attention in the short term, as well as the long term. This paper will discuss methods available to gather the right data, combining online monitoring, offline testing, and real time information. Once that data is available, it needs to be filtered and presented in such a way that the engineer's energy and resources are directed to those assets that need it the most. The goal is to provide the engineer with the ability to prolong an asset's life, and to be able to defer the replacement of an asset, and defer CAPEX expenditure, where possible while managing risk to the system and meeting the expectations of all stakeholders.

KEYWORDS

Asset Management, Smart Grid, Monitoring, Testing, Data, CAPEX, Risk

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I. DATA

Limitations

There is a limit to how much data we can store. In the past, the limiting factor was how large your filing cabinet was. Or, how many filing cabinets you had. Today, the limit is on hard drive size. In 2007, the amount of data that was being recorded, be it from personal computing, credit card companies, banking, online sensors, etc. surpassed the amount of available digital storage. A particle-physics laboratory in Europe, the Large Hadron Collider at CERN, for example, generates 40 terabytes of data every second from experiments. The scientists in charge of these experiments can only capture the data that they can contain and process, and let the rest run free.

Table 1 below illustrates the units assigned to bit sizes by the International Bureau of Weights and Measures. Examining the last two lines of the graphic, it becomes clear that the amount of digital data is increasing rapidly, and isn't likely to slow down in the near future [1,2].

TABLE I
Units of Bit Sizes Currently Assigned

Data inflation 2

Unit	Size	What it means
Bit (b)	1 or 0	Short for "binary digit", after the binary code (1 or 0) computers use to store and process data
Byte (B)	8 bits	Enough information to create an English letter or number in computer code. It is the basic unit of computing
Kilobyte (KB)	1,000, or 2^{10}, bytes	From "thousand" in Greek. One page of typed text is 2KB
Megabyte (MB)	1,000KB; 2^{20} bytes	From "large" in Greek. The complete works of Shakespeare total 5MB. A typical pop song is about 4MB
Gigabyte (GB)	1,000MB; 2^{30} bytes	From "giant" in Greek. A two-hour film can be compressed into 1-2GB
Terabyte (TB)	1,000GB; 2^{40} bytes	From "monster" in Greek. All the catalogued books in America's Library of Congress total 15TB
Petabyte (PB)	1,000TB; 2^{50} bytes	All letters delivered by America's postal service this year will amount to around 5PB. Google processes around 1PB every hour
Exabyte (EB)	1,000PB; 2^{60} bytes	Equivalent to 10 billion copies of *The Economist*
Zettabyte (ZB)	1,000EB; 2^{70} bytes	The total amount of information in existence this year is forecast to be around 1.2ZB
Yottabyte (YB)	1,000ZB; 2^{80} bytes	Currently too big to imagine

Source: *The Economist*

The prefixes are set by an intergovernmental group, the International Bureau of Weights and Measures. Yotta and Zetta were added in 1991; terms for larger amounts have yet to be established.

Management

With all of this data available at the click of a button, the focus becomes how to handle the vast amounts of data. The key is to obtain the necessary, valid data, and make it usable and useful. As a result of the recent financial crisis in the United Stated, it was made evident that banks and rating agencies were using models and algorithms that put to use vast amounts of data, but that didn't reflect real world financial risk [1,2,3]. Even with all of the data they were able to use, their models didn't work correctly. In the end, we are only talking about models; it is important to keep reality in clear view while attempting to extract valuable information from this mountain of data.

Data Mining

Datamining is the process of extracting synthesized and previously recorded knowledge from large databases [4,5,6,7,8]. With all of this data now available, and hopefully managed properly, it can and should be put to use. It is now possible, with the amounts of data available, and with the more advanced computing techniques also available, to spot trends in business, to learn about diseases and how they affect the body, to combat crime, and to improve on areas of weakness that would otherwise go unnoticed [3]. In order to do these things, however, the proper software and algorithms need to be in place.

It may not be obvious, but there is a link between data mining, hurricanes, and a popular breakfast pastry. In 2004, Wal-Mart hired National Cash Register (NCR), and their data warehousing branch Teradata, to analyze their massive sales record data. In using advanced analytics to uncover trends, it was discovered that when a hurricane was forecast, people tended to buy more batteries and flashlights. This shouldn't come as much of a surprise, as hurricanes have a way of knocking power out for extended periods of time. However, it was also discovered that people were also stocking up on Pop-Tarts, a breakfast pastry that doesn't require cooking. It makes perfect sense that a food such as this would be a handy thing to have if the power goes out; Wal-Mart may never have known to stock up on these as a hurricane approaches, however, without having first used analytics to comb through their massive amounts of data [9].

II. GENERATING DATA

Data and Analysis

Asset owners collect asset data to understand the nature of the asset groups we have – by manufacturer, by design, by location, by impact or criticality. Condition data is collected as part of an iterative process to identify actions – maintain, replace. Condition and operational data may require both short term intervention and longer term investment (10).

Data may be used in several ways:

- By itself and with reference to its own history, as with the operating time on a breaker, looking for variation against 'expected' values
- In synthesis/combination with other available data – transformer load and top oil temperature, noting that a correlation may be time delayed
- In aggregation with other individual units – does one unit stand out? Does one unit have an operating time within specification but which is slower than others in the same family? Is the relationship between two parameters not one of cause and effect, but one of two effects deriving from a common cause?

Example: SFRA testing

Sweep Frequency Response Analysis, SFRA, is a test which investigates the mechanical integrity of power transformers (11, 12). A signal is injected into the test object – a winding, for example – at a given frequency and the resulting signal at the other end is measured. The results are plotted in dB's and give a transfer function measurement for the test object – a 'fingerprint' for the winding. The SFRA test is very sensitive to variations in inductances and capacitances within the transformer and it is these variations which are sought and investigated as they may relate to movement of the windings within the transformer.

The best way to use SFRA is through comparison of a current result with a previous result – ensuring that the transformer is in the same physical state for tap positions, presence of oil, status of other terminals in terms of connections and grounding. The original test provides a bench mark, and any subsequent tests are performed when there is suitable motivation – that is, when there is suspicion of an event which may have caused mechanical movement of the windings: after a through fault, after transformer relocation or during commissioning itself to provide a baseline. There have been research projects to look at on line SFRA but this work has not yielded any practical field deployable systems.

As an example, Figure 2 shows the variation between two HV winding SFRA measurements; these are open circuit measurements with all other windings ungrounded.

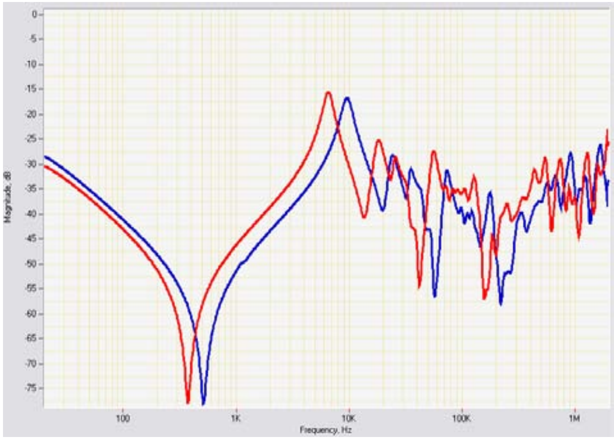

Fig. 2. SFRA Baseline and subsequent SFRA measurement

If the transformer winding under test had not changed – no variations in the inductances or capacitances – then we would expect the two results to overlay. As it is, in this case, there is significant variation between the two results. Subsequent investigation led to the discovery of both winding deformation and movement relative to other windings on the same core limb.

In terms of asset management, SFRA was a useful test. But we note here that it is a test which is not performed without appropriate motivation. The results are provided on an ‘as needs’ basis rather than regularly or continuously. This type of longer term testing regime has great value in relation to through faults which are relatively rare but which could have a serious consequence.

Example: Dissolved Gas Analysis testing

Dissolved Gas Analysis (DGA) is a well understood test for determination of transformer condition; there are many standards available for interpretation of the results (13, 14); heuristic approaches are valuable but may be misleading in novel situations (1).

Regular samples, particularly for larger or more critical units, yields a regular view on transformer condition, with a good DGA program giving early indication of failure in up to 50 % of incipient failures. Data from annual sampling though relatively sparse, is thus effective as an asset management tool. Figure 3 gives an indication of key DGA levels for a transformer which subsequently failed.

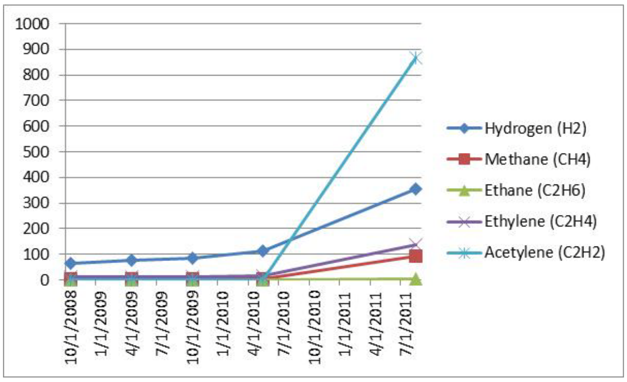

Fig. 3. DGA key gas evolution over time – laboratory analysis

Although most gas levels had been stable for some time, the hydrogen had been showing an increasing trend and the final failure brought a dramatic increase in most dissolved gas parameters.

By itself, regular DGA is a useful asset management tool in assisting with the identification of suspect units. An on-line DGA monitor gives further information, bridging the 'silence between samples' which can mask rapid deterioration. It can be seen from the data in Figure 3 that an on-line monitor may have been able to give early warning of the failure if it had been applied and there was a 'graceful' element to the deterioration. Of course, if the failure was sudden and catastrophic there may have been no ability to act.

Figure 4 shows the results from an on line system employed on a large transmission transformer. The levels of hydrogen show two dramatic changes in short spaces of time. These changes were significant enough to warrant investigation but, unfortunately, went unattended and the transformer failed.

This raises the questions of not only how effective the monitoring system is, but also what plans are in place to respond to step changes. These are both asset management questions which require procedures and protocols be set up to manage the transformer, the monitoring system and to respond to alerts and alarms from the monitoring system.

It is interesting to note that DGA for transformers covers the possibilities of either regular or occasional *ad hoc* sampling and continuous on line monitoring. Both require their own and individual asset management approaches.

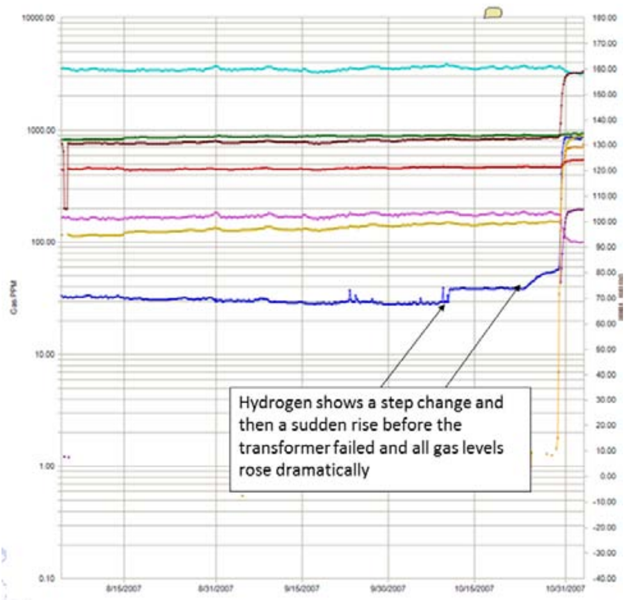

Fig. 4. DGA key gas evolution over time – on-line analysis

III. SMART ANALYSIS

Smart Grid

What do all the data, decisions and analysis have to do with the smart grid? Many of the ‘smarts’ which are put into the condition evaluation of substation equipment are automated algorithms which often require ‘checking by adults’ (10) – people experienced in the origins of data and its interpretation. With an ageing workforce, such people are becoming less common (11).

As an example, the ‘flash crash of 2:45’, a stock market crash in 2010 was one which was, in theory, the result of analysis algorithms responding to the market in unforeseen ways (12). 9% of the market value disappeared in seconds. A subsequent theory that the whole event was based on erroneous data entry is salutary. Algorithms unobserved were the source of an event related to Amazon: the website price for a book “The Making of a Fly”, which was out of print, available from two suppliers. At one point the book, which retailed at $35, was on sale for in excess of $1.7 million. No one bought the book, but the price continued to rise to over $23.6 million. The cause was a set of algorithms two vendors used, which were based on the other vendor’s price. The control loops weren’t able to recognize ‘common sense’ and escalated in a closed loop. A single human intervention was all it took to correct the situation (10).

Analytics

We must ensure that as we develop the rules and criteria of smart grid that we keep the human element central. The smart grid must thus react more quickly to external events, and in such a way that it is predictable and the algorithms employed well understood. The day everything goes dark, a flash crash of the voltage due to a huge number of devices simultaneously switching in to take advantage of low electric prices, may not be far away (13).

It is important to plan ahead for transformer failure and consequences. Both short term response to issues and longer term response in terms of capital programs need to be used to support the safe operation of the entire fleet (19, 20).

The data generated by both online and offline testing may be voluminous and generated quite frequently, but the data is required in terms of both the importance and the frequency of the decision being made. It is a challenge to identify appropriate monitoring solutions and testing regimes which are both efficient and cost effective. There is a way to view the process of deployment in terms of a double control loop, which links the short term 'tactical response' and longer term 'strategic response', as shown in Figure 6.

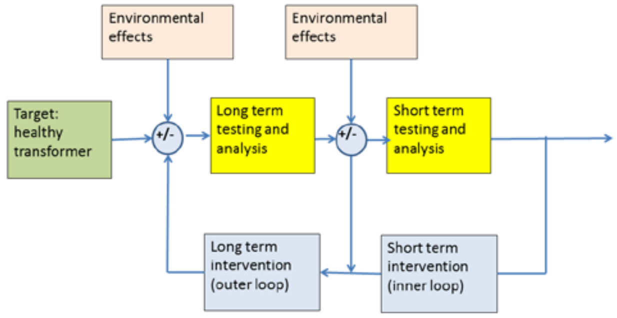

Fig. 6. Long and Short Term Control Loops: transformers

Unfortunately, the use of the double control loop does not reflect the dynamic nature of the situation completely: there is a spectrum of data gathering and time scales, and there is a spectrum of responses. However, the double loop helps focus on short term activities and longer term goals.

The role of asset management is to understand the loops and how they enable us to move from one type of response to another. At some point, the response time in the outer loop is no longer adequate to manage an asset's health. At such a point, more monitoring and testing may be necessary, but we must also plan for deeper intervention: refurbishment and replacement.

IV. CONCLUSIONS

Asset management is a discipline which is becoming more holistic and far reaching in terms of asset lives. Data being used to make decisions is not necessarily representative of all data that may be seen. Algorithms used to analyze data and make decisions must be monitored themselves so as to ensure that the outcomes are not unexpected. As the work force ages, encapsulation of tacit knowledge becomes more pressing and more critical – to ensure that the smart grid remains smart, and our electric system remains youthful and alive.

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