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CORRELATIVE ANALYSES CONSIDERING DIFFERENT PARAMETERS IN ORDER TO INCREASE THE RELIABILITY OF ASSET HEALTH ASSESSMENT

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SUMMARY

Reliable electrical assets are essential for generating, transmitting and distributing reliable energy. Therefore the knowledge of the condition of an asset is extremely important. Offline condition assessment methods are established and used since decades with success. Nevertheless, they give a screenshot of the asset in the moment that the measurements are taken. Despite this, the development of the health condition can only be estimated and the development of incipient faults can be missed.

Nowadays besides offline methods, more comprehensive online monitoring approaches for the assets fleets combined with analytic models and severity analyses are used in order to capture changing conditions in real time and to predict critical situations. For an example, UHF partial discharge monitoring for GIS is established and well accepted for more than 20 years already.

In order to efficiently assess the condition of an asset, the failure mechanism, its associated monitoring parameter(s) and the dedicated analytic model must be known and must be considered in its completeness. Comparing of different parameters is important in order to achieve a holistic view on a specific asset condition.

This paper will give an overview about the changed environment in the electrical industry and why condition monitoring gaining more importance. Furthermore it will be discussed how the assessment reliability can be improved by using severity checks, based on correlative analyses of different monitored input data, assets and analytic models (e.g. bubbling temperature, Dissolved Gas Analyses Algorithms for transformers, Partial Discharge classification for GIS etc.) and giving operators a more easy to understand information instead of providing overwhelming amount of scattered data. It will be shown, how severity analyses principles can be applied for substation equipment on examples of transformers, gas insulated and hybrid (breakers and disconnect switches metal encapsulated and SF6 insulated) switchgear.

Furthermore it will be shown on a real example of a transformer failure, how different monitored parameter (in this example online Dissolved Gas Analysis and UHF Partial Discharge monitoring) can complement each other in order to achieve a higher accuracy in assessing the health of an asset and to improve the coverage of developing faults with a different dynamic in its development.

KEYWORDS

SEVERITY ANALYSES

ONLINE MONITORING

HEALTH ASSESSMENT

CONDITION BASED MAINTENANCE

INTRODUCTION

The face of electrical energy production, transmission and distribution has changed significantly over the last few decades. The deregulation of the energy market, along with the privatization of the before public owned utilities, has often lead to more profit oriented enterprises. Furthermore power generation, transmission and distribution were separated in different divisions and privatized separately. Under pressure to increase profits and efficiency, it was popular to outsource maintenance and other technical services. The new created generation, transmission and distribution companies carefully select their investments in new equipment or in the renewal of equipment. Investments are sometimes limited to the replacement of out of date or failed assets. Even failed equipment has not been replaced in some cases, solely due to pure financial reasons. The distribution and transmission companies were especially affected by increasing prices from the major power generation utilities and much lower prices in the retail markets, for example in 2000 and 2001 in California [1]. The result was the weakening of the electrical network, in a number of cases.

Today after overcoming these teething troubles by introducing additional measures (US in 2002 and in the EU in 2007), private investment in the energy sector has led to the development of efficient equipment and efficient methods for operating the assets, assessing the condition of major network components to maintain the ability to deliver electrical energy and to use the equipment till its real end of live. This is today an important driver for the rapid development of innovative condition monitoring.

The change in global energy politics has driven the electrical power industry not only for more efficient solutions, but also to use renewable energy resources, like wind power, geothermic power and solar power. The energy production will become more and more decentralized. Sometimes the energy will be generated far away from the consumption centers, which is the case in terms of offshore wind farms (e.g. in the North Sea). The decentralized power generation leads into a reconfiguring especially of the transmission network. The electrical energy now needs to be transmitted from the regions, where it is generated to the load centers. The control of the decentralized network will be taken over by Smart Grid technologies. Due to the permanently changing load flows, the impact of failing major equipment can only be analyzed by complex simulation. Even the importance of the key components can change with the change of direction of the load flow, which is difficult to integrate into automated reliability and profitability calculations/ simulations. In this respect the collection of online condition data is essential.

Due to the above described changes in the technical and political environment, condition monitoring of key assets is gaining more and more importance.

Key assets of electrical networks receive, based on the above described circumstances, a high attention in regards to condition assessment. Offline condition assessment methods are established and used since decades with success. Nevertheless, they give a snap shot of the asset in the moment when the measurements are taken. Despite this, changes of the health condition can only be estimated and the development of incipient faults can be missed.

Introducing online monitoring in the past most often was just limited to some independent parameters. Users struggled accessing the true overall condition of an asset. A typical statement was and still is: “I got an alarm, but what that does it mean to my asset?” Confusions prevailed over clear decisions in lots of cases. “False Alarms” leaded and lead in not trusting installed monitoring solutions. A common opinion still is that always the help of experts in that field is needed.

Nowadays more comprehensive online monitoring approaches for assets combined with analytic models and severity analyzes are used in order to capture changing conditions in real time and to predict critical situations. The implementation of procedures for operators and maintenance in regards to asset monitoring are becoming more common.

Correlative analysis are gaining more and more importance as it enables the user to do severity analyses by using different parameters which are supporting or contradicting each other in its individual asset condition prediction. In order to efficiently assess the condition of an asset, the failure mechanism, its associated monitoring parameter(s) and the dedicated analytic model must be known and must be considered in its completeness.

ANALYTIC MODELS - GENERATING INFORMATION INSTEAD OF DATA

The knowledge of the failure statistics and the past experience of a certain asset as well as the understanding of failure mechanisms combined with the criticality are essential to choose the right parameter for an assessment and to build up analytic models. Today asset assessment will be mostly understand as to be used to preventing failures and to enable Condition Based Maintenance (CBM). Online condition assessment could be also a powerful tool for asset operation. The prediction of a certain load condition and the risk status of electrical assets can be used for dynamic loading. Once the pressure on the owners regarding financial efficiency increases, dynamic loading becomes more and more important.

Presenting "only" data can mislead to poor maintenance/ operational decisions and unnecessary interventions, which usually have the potential to introduce new risks. Fig. 1 shows this scattered data approach. Often it is difficult to analyze the scattered data by users. Data are analyzed separately in disregards of the possible relationship to other parameters or even legacy data.

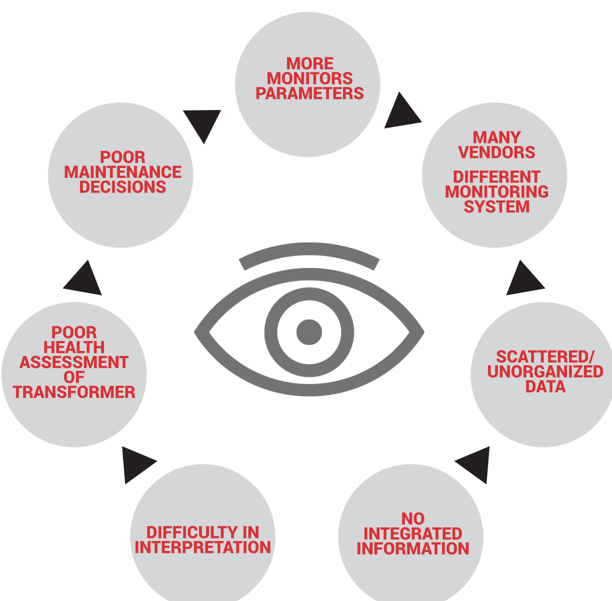

Fig. 1: Scattered data approach

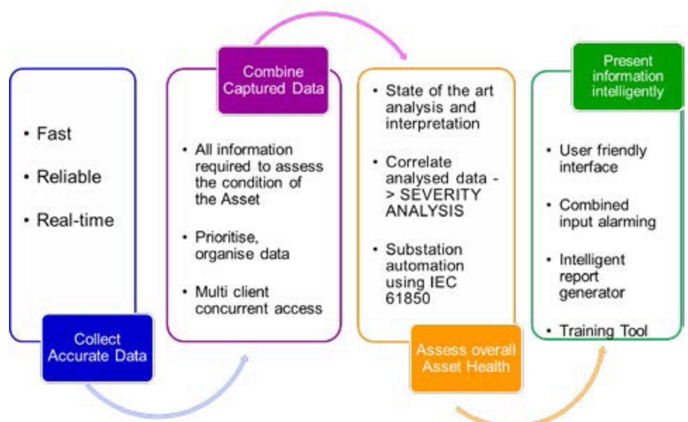

Fig. 2: Information extraction block diagram

A practical example could be partial discharge (PD) in a Hybrid Breaker installation captured with a single UHF sensor. If the detected PD is considered solely, it could lead to the decision to open up the Hybrid installation and trying to find the failure. Considering also the fact, that gas filled bushings are used (low capacitance/ almost no low pass filter behavior), it would be necessary to contemplate the possibility that UHF can enter from the outside. PD appearance and disappearance for longer periods, mostly related to climatic conditions, will give a clear sign of external discharges (e.g., surface discharges on the silicon surface of the bushings). At first instance the example seems very basic, but in reality it is a common false decision taken based on analyzes of one parameter solely (valid also for GIS overhead line bays).

Besides reliable capturing the data for the chosen parameters, relevant information needs to be extracted. Using a PD example again it would mean, that PD impulses must be related to its position in phase of the line voltage, which then allow to combine the single impulses to different pattern types (PRPD pattern – phase resolved partial discharge pattern; 3D pattern; point of wave etc.). Adding the time of occurrence will also give additional information for the analysis of the PD. Comparing for example additionally the time of arrival or/and amplitudes of the same PD impulses at different sensors will give further useful information about the origin of the PD. Fig. 2 shows a schematic of a possible approach for information extraction out of collected data. Fig. 3 shows how the collected data will be analyzed through different abstraction levels (analyzed by simple logic or sophisticated artificial neuronal network approaches, fuzzy logic etc.) and further verified with the help of other related data (e.g. PD and Dissolved Gas Analyses – DGA – for transformers).

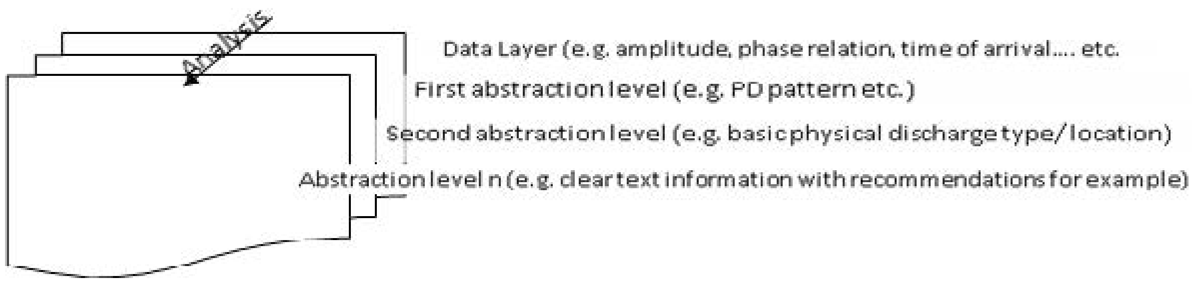

Fig. 3: Diagram data abstraction level

The abstraction level can be arbitrary continued. Figure 4 shows the abstraction level at network layer (left picture) and the substation layer (right picture) for the substation under concern.

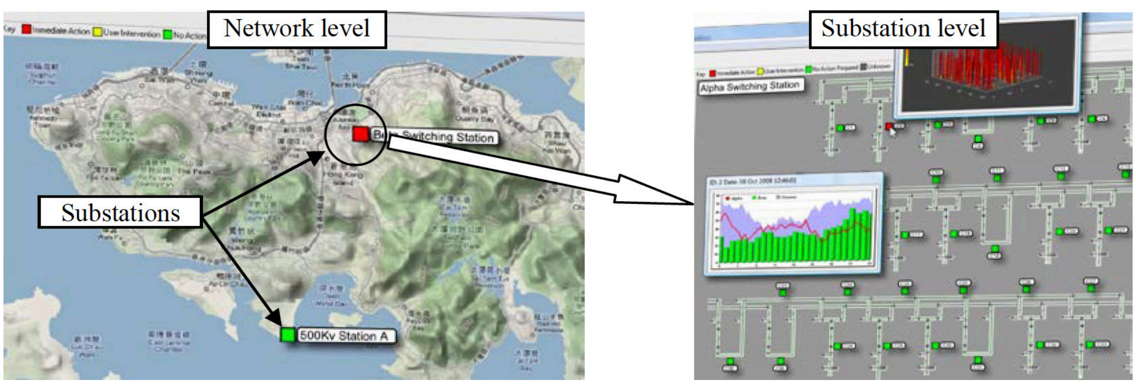

Figure 4: Information abstraction from network and substation level overview

In order to access a certain alarm or warning condition, different parameters should be correlated to each other, including online and offline data, as well as data from different sources, e.g., SCADA systems, periodical visual checks, load data etc. This would allow relating complementary parameters. Automated correlation of data can be done for online data. Offline available data needs to be reviewed manually or via and interface uploaded into an online tool which is able to marry online and offline data. Further below it will be discussed, how different parameters/analytical models can complement each other in order to identify possible incipient faults.

ANALYTICS AND CORRELATIVE ANALYSES

Analytics concerns about a certain parameter as correlative analyses combines information from different parameters and from different sources. Both are using abstractions algorithms (as described above). The aim is to extract information. In the bubbling temperature model for example the hotspot temperature is used to determine the temperature at which the gas bubble generation starts. To enable this calculation, a set of different parameters need to be known, like the hot spot temperature itself, the moisture in oil, the gas content in oil, the pressure at the hot spot, the temperature of the oil at the moisture sensor and the ambient temperature.

In general it will be distinguished between diagnostic tools based on single parameters and parameter sets like Duval triangle in terms of DGA and localization techniques for PD and analytic models like bubbling temperature, DGA analytics based on artificial neuronal networks as shown in fig. 5, cooler efficiency calculation, remaining thermal life modeling automated PD classification, etc. Some of the models found already their way into the international standards and recommendations like for example in [6].

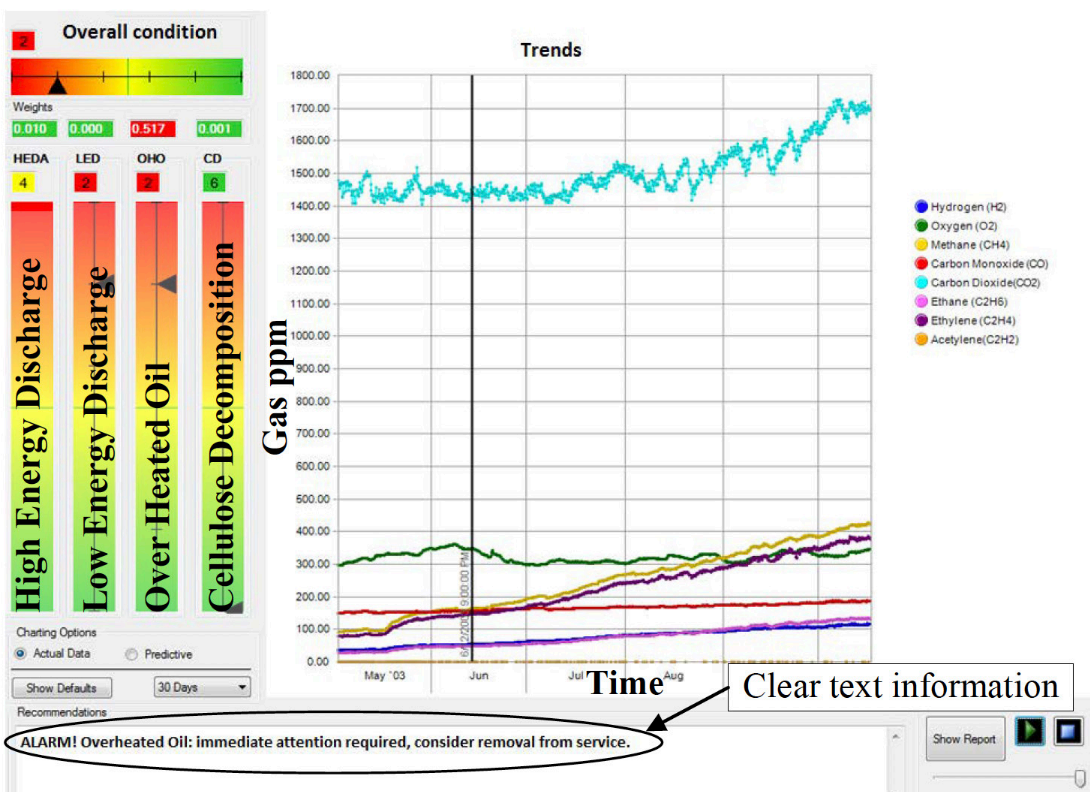

Fig. 5: Example for an analytic tool for DGA

The difference between analytics and diagnostic tools is that analytic tools give an indication about the condition of an asset ("good or bad indication") and diagnostic tools are used to identify/ assess an upcoming fault notified by analytics. Diagnostic tools usually are not allowing a good and bad decision. They are focusing on the type of defect, the location of the defect etc., in order to provide the bases for a risk assessment for a detected abnormality. The risk together with the importance of the asset will usually be the input of the Condition based Maintenance (CBM) decision making process.

Correlative analyses will make use of one or several relevant parameters or even results out of the analytics in order to support or to contradict a certain assessment. That will increase the confidence in the result of the risk assessment drastically. Table 1 shows an example of correlative analytic models for failures in the magnetic circuit considering different parameters and its detection time.

Table 1: Magnetic circuit correlative analyses

	Component	Failure mechanisms	Analytical model	Measured signals/ parameters	Detection time
Magnetic Circuit	Core ground lead Magnetic shield	Loss of core ground Unintentional core and shield grounds create problems and discharges	DGA Model	Hydrogen or multi-gas	Hours
			Core Ground Current Model	Core ground current	Days
			Gas Accumulation Rate Model	Gas accumulation	Real time
			Thermal Model	Core hotspot (Fiber) Temperature	Hours
			PD Model	PD	Real Time

In the example shown in table 1 there are 5 different analytic models available, which can support or contradict a certain assessment. For each of the models different input parameters need to be gathered and each of the models/ parameters has its own detection time. It is useful to use more than only one analytic model for a certain failure mechanism. In the above example most probably the DGA model, the core ground current model and the PD model would be the best fit. In that case the parameters to measure are dissolved gases, PD and the core ground current.

Similar models are made for different kind of failure mechanisms in the transformer main tank, LTC's, bushings, cooling systems, GIS etc. Regarding the importance of that particular asset and its history a decision can be made, which types of failures need to be considered for monitoring.

PRACTICAL EXAMPLE

In the discussed case a single phase, Extra High Voltage (EHV) autotransformer is equipped with the typical EHV monitoring package: DGA, bushing monitoring and temperature monitoring. Furthermore legacy data are available. Recently 6 UHF PD sensors have been installed and connected to a permanent monitoring system. The transformer had been 3 month in service and experienced a catastrophic failure. DGA and bushing monitor did not alarm, but the PD monitor showed strong PD activity 8 hours prior the fault occurred. This shows that correlative analyses not only support or contradict each other, but also can complement each other as see in the described case. One method for example can covering the time period, where for example the other method would be to slow (like DGA due to the time needed to distribute the generated gas) [7]. Furthermore having that history data and that experience now, similar cases for the same transformer type can be handled.

CONCLUSION

The power industry today demands, besides the conventional gauges and well established monitored parameters like online DGA, a more comprehensive monitoring approach in order to implement CBM principles with the goal to use assets more efficiently and more optimized, as well as detecting incipient fault already in an early stage.

Analytic models will help to filter important information out of scattered monitoring data. By using correlative analyses the confidence in asset health assessments can be improved as shown also in the example above, where one method can miss an important abnormality while another is detecting immediately.

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SHORT BIO OF MAIN AUTHOR

Emilio Morales is the Technical Application Specialist in Transformer applications at Qualitrol Company LLC. His main focus is to support solutions in comprehensive monitoring for Transformer applications

Emilio attended Nuevo Leon State University in Mexico from 1975 to 1979, receiving his Bachelor of Science degree in Electro Mechanical Engineering in 1980. Emilio has spent his entire career in design in the power transformer manufacturing industry. His has over 30 years of experience in design which includes transformers up to 500 MVA and 500 kV as well as furnace and rectifier transformers and different type of reactors. He is member of the IEEE/PES Transformer Committee, IEC and CIGRE and actively participating in different task forces.

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