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TRANSFORMER OIL BDV ONLINE MONITORING

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INTRODUCTION

Power transformers are the backbone of the upcoming Smart Grid. However, the aging of their components, especially of transformer oil and paper, will reduce their availability in near future dramatically. [1] Currently mostly time-based maintenance schedule schemes for transformers are applied. But, state-based predictive maintenance schedules are urgently required to be able to cope with the changes due to aging processes. Presented is a new approach to transformer oil monitoring which allows predictive maintenance resulting in prolonging the lifetime of power transformers in the grids. The measured parameters are physico-chemical properties of transformer oil including moisture content (relative humidity) via multi-frequency ultrasound spectroscopy. Currently the electrical property dielectric strength (breakdown voltage – BDV) is inferred by intelligent software tools (multivariate statistics) from the measured ultrasound parameters. [1,2] Further an oil aging assessment module is in implementation process. The application to the transformer takes place in online mode by attaching a bypass system to the transformer, where a measurement cell with ultrasound transducer is included, see Fig 1 and Fig 2.

PROBLEM – DIELECTRIC STRENGTH

The most important protection means of the transformer is the transformer oil, which due to its changes during its lifetime is bearing concise information on the aging of the transformer (oil). [1,2] This information is provided along with the condition of its electrical insulation ability, which is affecting safety and reliability of the operation modes of the transformer.

The frequent variation of temperature causes a forced aging of the transformer oil and the paper. [1]

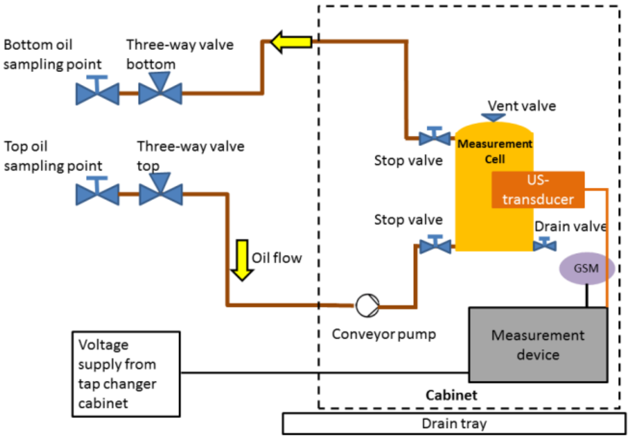

Fig 1 Bypass online monitoring scheme

Fig 2 Realization of monitoring system

Lacking an integrated online-monitoring of transformers in the grids only lab examinations of transformer oil are taking place – sometimes never, sometimes starting after 5-10 service years, sometimes in intervals from 1-2 years, if the transformer has reached a "critical age”. But

– taking an oil sample from a transformer at a certain time within a yearly or a half-yearly period provides no really significant information about the real safety state of the transformer or its insulation, respectively. So far, transformer-oil samples, taken in the traditional way, are only selective snapshots of the transformer safety state which will rapidly change more and more and in future even in shorter time intervals.

Especially BDV is one of the most important oil parameters for the assessment of electrical safety of the transformer. If BDV is lying in the vicinity of 30 kV or even reaching it than the transformer should be turned off. For this reason, the BDV is a very critical parameter. [1] But how far can we rely on the standard measurement according to IEC 60156? [3]

BDV INVESTIGATION AT A GERMAN ENERGY SUPPLIER

In Fig 3 the variation of BDV (green line) for over 3.000 transformers of a German energy supplier High Voltage Grid is shown. It is displayed in dependence of acidity (TAN, orange line) and sorted for each acidity stage (e.g. TAN = 0.03) according to water content (in ppm, blue line). So one can see that even for the majority of transformers (TAN= 0.03, ca. 1350 transformers in the Grid) the BDV is of high variance, but has in the average for these transformers a BDV between 67.8 kV and 65.2 kV, which is supposed to be sufficient in total. What as well can be seen is the global tendency of BDV to decrease on the long term with increasing acidity. The numbers in the green BDV “zone” indicate average values for different intervals.

As a further example the uncertainty of BDV measurements for the same water content (3 ppm) and the same acidity (TAN = 0.03) from over 200 transformers in the transformer grid of a German energy supplier is shown in Fig 4. The BDV-distribution is displayed for all transformers with the 2 oil parameters mentioned before. On the y-axis the number of transformers is counted in intervals of 10. Peaks of the BDV–distribution are 65 kV and 70 kV with 60 transformers each. The span width for all BDV measurements is 50 kV.

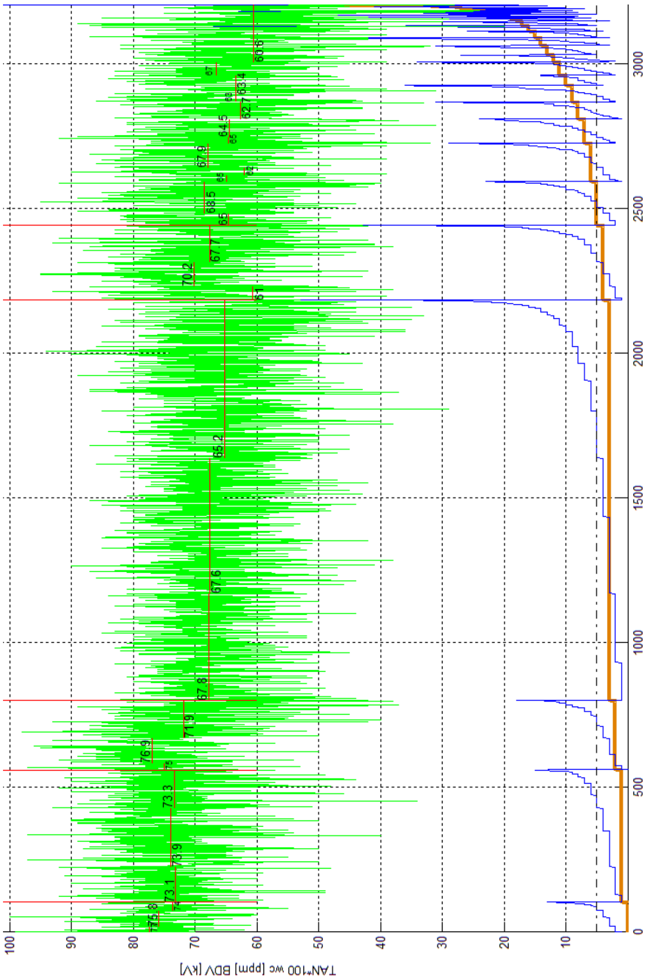

Fig 3 BDV variance from transformers in the grid of a German energy supplier

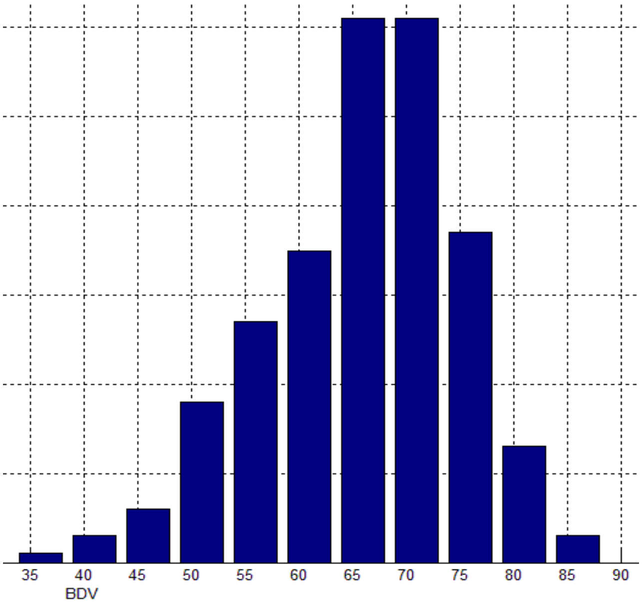

Fig 4 BDV variance of over 200 transformers

STATISTICAL AND OTHER PROBLEMS WITH BDV

The problems with “normal” BDV measurements are especially [3]

- that temperature dependency of BDV is not considered in IEC 60156 standard,
- that 6 discharges are very “poor” for statistically significance,
- that the influences of aging by-products and particles are not separately treated,
- that the BDV-values are not normal-distributed, but obey to a Weibull distribution.

Disregarding all of these problems, as it is done when performing BDV measurements according to IEC 60156 Standard, leads to the high variance of BDV as observed in Fig 3 and Fig 4.

SOLUTION – ONLINE BDV MEASUREMENTS

To get rid of or to overcome some of the above-mentioned problems with the aim to reduce BDV variance a continuously monitoring of BDV of transformer oil under operating conditions is mandatory. Taking samples at high frequency in urgent cases and evaluating them in labs would be too cost-expensive and time-consuming.

A statistical BDV inference system was developed based on the continuous measurement of multi-frequency ultrasound spectra of the oil, carried out by the bypass online system shown in Fig 2.

Using this online measurement system, the following advantages are obvious:

- The same oil is continuously monitored at its actual temperature. The ultrasound measurement system is capable of tuning to this oil in current use.
- As much measurements as needed could be made for statistical significance. Moreover, the measured oil volume changes permanently.
- Trends and all necessary statistics can be provided; daily/seasonal changes can be considered. So an actual BDV decrease over a longer period can be detected.
- The combination with other oil parameter online measurements (e.g. aging) will improve the quality of BDV determination (by inference).

IIMPLEMENTATION ON SITE AND WORKING PRINCIPLE

A pilot system as shown in Fig 2 was installed at a transformer from a German energy supplier, shown in Fig 5.

The full installation time was about two hours. The system shown in Fig 2 and Fig 5 was connected to top oil sampling valve (oil outlet from transformer = oil inlet to measuring system) and bottom oil sampling valve (oil inlet to transformer again = oil outlet from measuring system) via two hoses with bayonet couplings. At the measuring system two additional sampling valves are provided which allow taking oil samples as needed in a much easier way as before, see in Fig 2 on the lower right with closed orange valves. Then top oil from the transformer was pumped by a conveyor pump to the left part of the measurement system.

Fig 5 Measurement system at transformer

The right part was closed at this moment. Degassing took place at the highest point of circulation system, where a venting valve is located by letting oil overflow from the left part. The same procedure took place for the right part. After degassing the bypass system was in circulation mode as shown in Fig 2 – the oil valves are in flow direction. Measurements take place in batch processing controlled by a computer and the electronic module for ultrasonic measurements after pump stops. The measurement cycles can be remotely controlled.

COMMUNICATION TO SERVER

The measurement results are stored by an electronic control module (upper right in Fig 2) to a tiny computer with communication possibility. By this way they are transferred to a database on a server, installed at a company´s location. After post-processing the data are directly transmitted to smartphones, notebooks or other devices via a secure communication line to an app, see Fig 6.

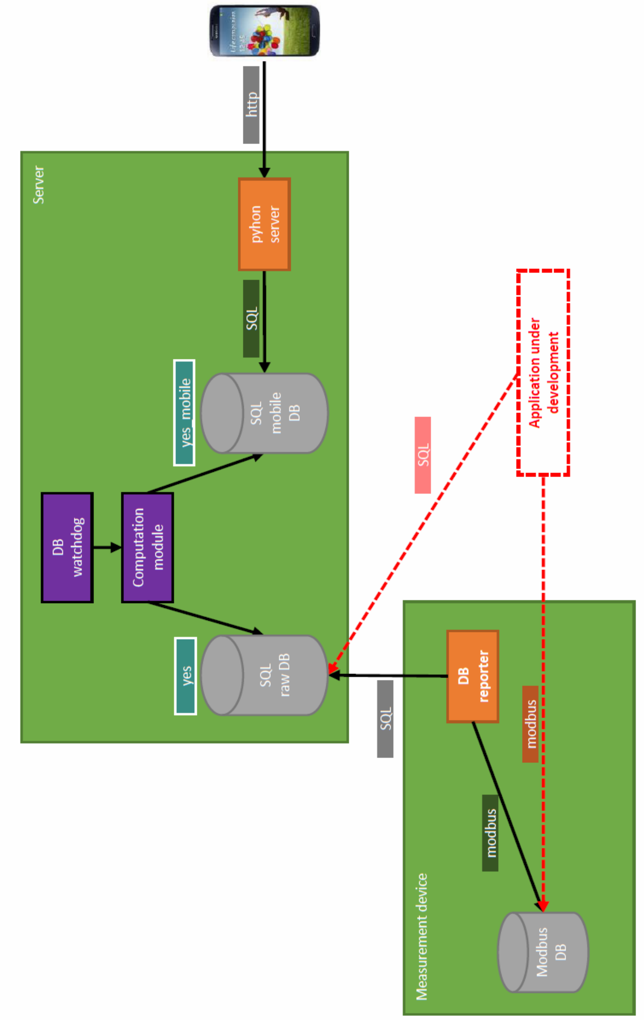

Fig 6 Communication infrastructure

RESULTS

The results of the BDV measurements are shown by app screenshots from a smartphone, see Fig 7 and Fig 8. On the bottom line of each figure one can see the first and the last measurement date (20.4.16 and 15.5./11.6.16).

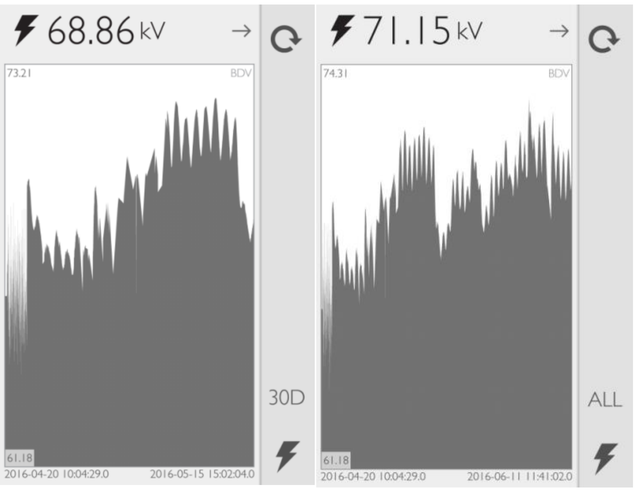

Fig 7 and 8 App screenshots of BDV

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