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HVAC에 의한 On-line, Off-line PD 모니터링

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On-line and Off-line Partial Discharge Monitoring System with HVAC Testing

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Abstract : The paper considers the relation between on-line monitoring and diagnostics on the one hand and high-voltage (HV) withstand and partial discharge (PD) on-site testing on the other. HV testing supplies the basic data (fingerprints) for diagnostics. In case of warnings by on-line diagnostic systems, off-line withstand and PD testing delivers the best possible information about defects and enables the classification of the risk. Because alternating voltage (AC) is the most important test voltage, the AC generation on site is considered. Frequency tuned resonant (ACRF) test systems are best adapted to on-site conditions. They can be simply combined with PD measuring equipment. The available ACRF test systems and their application to electric power equipment -from cable systems to power transformers - is described

Key Words : On-line monitoring, High-voltage (HV) withstand, Partial discharge

1. Introduction

On-line monitoring has the big advantage that it indicates certain measurands of apparatus without interruption of service. The measurands might be related to volume phenomena or to weak point phenomena (e. g. PD). But in any case, they are indirect results requiring interpretation by knowledge rules. Such knowledge rules are based on basic research, but should also be related to results of previous type, routine and on-site tests. A remarkable improvement of the conclusions is reached if in case of warning by the on-line diagnostic system an off-line withstand test combined with PD measurement (this means a combination of a direct test with an indirect measurement) is added. Such an off-line, onsite test enables PD measurements in a wide range of voltages, higher and lower than the operation voltage. This means on-line diagnostics and HV testing on site must not be considered as separate or even contrary methods. They complete each other in an excellent way.

It is good practice for nearly 100 years and a basic principle of insulation coordination [1] that the test voltage shall represent stresses in service. The horizontal standards for HV testing in test laboratories [2, 3] consider this principle by defining power frequency (45 to 65 Hz) lightning and switching impulse voltage (applicable for AC equipment). With respect to weak point detection by withstand voltage testing and PD measurement, voltages which represent power frequency are by far the most important. The application of direct or very low-frequency (VLF) voltage to AC insulation causes resistive instead of capacitance voltage distributions. Consequently the PD measuring results are much less representative than those measured at an AC voltage which is representative for power frequency. IEC Standards (e. g. [4, 5]) allow for AC on-site testing wider frequency ranges. This is considered by a frequency range 10 Hz to 500 Hz in the latest draft for the horizontal IEC Standard for HV testing on site. Using AC voltages of a certain frequency range of that overall range will deliver test results in close relation to the stresses in service. Therefore AC voltage generation on site will be considered more in detail.

2. HVAC Test System for PD Monitoring

The ACRL system operates at power frequency whereas the ACRL system needs a wider frequency range (e. g. 20 to 300 Hz). This certain disadvantage is more than compensated by the following series of advantages: Because of lower frequency at maximum load (20 Hz), ACRF systems have a higher equivalent test power at identical current. A reactor of tuneable inductance (ACRL) has higher losses than one of fixed inductance (ACRF), consequently the quality factor of an ACRF system is about twice of that of an ACRL system. The necessary feeding power is remarkable lower and can be supplied from a three phase system. Also the weight-to-power ration, which is an indication for the transportability, is about three to five-times better for ACRF systems than for ACRL systems. This is completed by an ACRF load range up to 10 times larger than that of ACRL system. The high robustness of ACRF systems comes from components without moving parts, whereas ACRL systems contain a reactor with a moving core and a conventional regulator transformer.

The static frequency converter (Fig. 1) (FC) of the ACRF system generates four switching pulses (of few 10 microseconds each) which may influence the PD measurement. In modern PD measuring devices (PD) they can be suppressed by triggered windowing (tw). But in many cases they can also remain on a PD pattern because they are simply identified as noise signals.

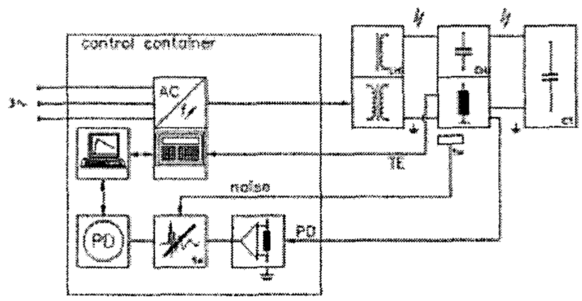

Fig. 1. ACRF test circuit for PD measurement.

3. Results and Discussion

PD measurement at variable frequency is not different from the well-known at power frequency. With respect to onsite measurements, there is an advantage of PD measurement at frequencies different from power frequency, because the noise signals are triggered to the latter. Fig. 2 shows the onsite measurement of a 400-kV-voltage transformer at 81 Hz in an open-air substation. Whereas the PD signals are in a stable phase position of the 81 Hz voltage (characterized by the red colour (C) which means high PD pulse rate), the up to ten times higher noise signals (E) are related to 50 Hz, but deliver a "grey background" of low density. Even such a high noise cannot prevent a successful PD pattern recognition.

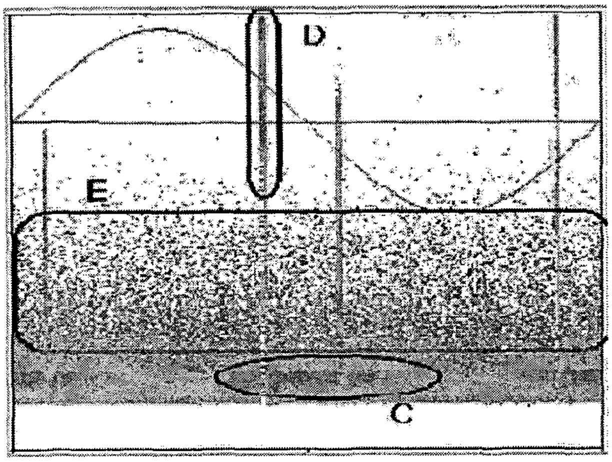

Fig. 2. Signal-to-noise relation for PD measurement at a frequency different from power frequency.

On-site testing of machines must be connected with PD and tan measurement. Whereas the PD behaviour is similar in a sufficiently wide frequency range [6], the dissipation factor depends on frequency by definition (power loss/capacitive apparent power). But more important than tan itself is its increase with voltage (Fig. 3) which is nearly independent of frequency. Therefore ACRF test systems completed with PD and tan measuring equipment are efficient tools for generator testing on site [6].

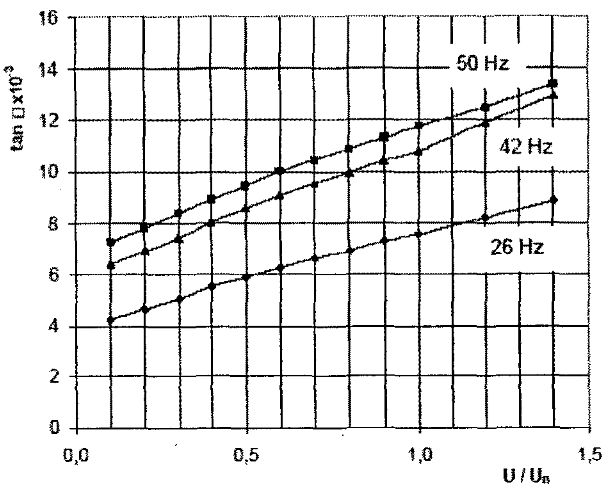

Fig. 3. Tanδ measurement of 137 MVA generator at 50, 42 and 26 Hz.

4. Conclusions

With respect to on-line monitoring and diagnostics, off-line testing and PD measurement is not unnecessary, but an important completion in case of a warning by the on-line diagnostic system. Off-line withstand testing in combination with PD measurement enables a classification of defects in connection with the life cycle record. It seems necessary to say that on-line monitoring and diagnostics have to take the experience of one century of HV insulation testing into account, especially when standards are under preparations. Vice versa, also the standards of HV testing should be modified with respect to later monitoring, because HV testing shall supply the necessary basic data (fingerprints) for diagnostics.

[Acknowledgement]

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