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전력 설비 시스템의 온라인 감시

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On-line Condition Monitoring for Electric Equipments

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Abstract : In, this paper, we consider 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, Diagnostic, High-voltage, Partial discharge

1. Introduction

The electric breakdown is a weak point phenomenon caused by a defect in the insulation. The defect might be the result of a production failure (to be detected by the routine test in factory) or a too high stress during transportation or an assembling fault (to be detected by the on-site test). But also the normal aging process of the whole insulation causes degradation as a volume phenomenon and only finally a weak point leading to breakdown. The described physical breakdown process enables the following classification of HV tests and measurements: Whether a certain defect is dangerous or not at a fixed test voltage level can only be decided by a HV withstand test which is therefore characterized as a "direct" test. This direct test needs no interpretation, the result interprets itself directly.

Each measurement of a different quantity and the conclusion for critical defects and breakdown requires a more or less physically or technically based knowledge rule. Therefore measurements deliver always an "indirect" test result of higher uncertainty than a direct test. Last but not least partial discharge (PD) measurements which measure also a weak point phenomena deliver a less uncertain result related to critical defects than dielectric measurands (e. g. tanδ) which are volume phenomena. The latter give only a rough indication if the aging process could lead to a critical defect (weak point) or not.

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.

2. Experiments

2-1 Frequency-tuned resonant test systems

Most test objects (see III.B to III.E) are capacitances and therefore HVAC test systems based on series resonant circuits have tremendous advantages compared with conventional test transformer. A resonant circuit is an oscillating circuit with the natural frequency which is excited with exactly that frequency.

Because the capacitance CT of the test object is fixed, there a two ways to reach resonance

- by tuning the inductance LH in such a way that fr becomes equal to the frequency of the supply power (50/60 Hz): inductance-tuned (ACRL) system (Fig. 1 (a));
- by the power supply via a frequency converter with exactly fr: frequency-tuned (ACRF) system (Fig. 1 (b)).

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.

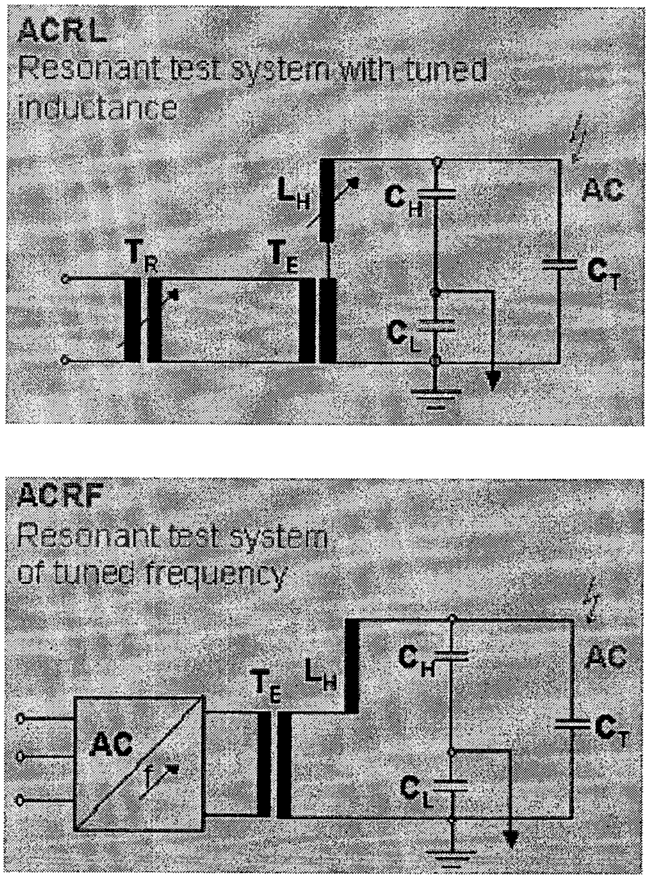

Fig. 1. Series resonant circuits of variable inductance (a: ACRL, 50 Hz) and variable frequency (b: ACRF, 20 to 300 Hz).

2-2 PD measurement at variable frequency

The static frequency converter (Fig. 2) (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.

3. Results and Discussion

Quite often withstand testing of power equipment in service is not applied, because utilities are afraid that it could damage or even destroy the equipment.

But when the test is performed with a well selected AC voltage amplitude (in relation to the standardized test voltage level for routine tests) and combined with a sensitive PD measurement, then this fear is not justified and the advantage of a direct test becomes evident. Because testing means *classification into equipment safe for service*, equipment which must stay under observation and equipment critical for service. If the HVAC withstand test results in a breakdown the equipment would have failed in service soon. The whole test should be performed as a step test (Fig. 3 shows an example) and all the time be observed by PD measurement. In addition to the selection of the withstand voltage level (Uw = n . Uo; usually 1,3 < n < 2) a voltage level shall be chosen below that PD should not exist (UPD = mUo; e. g. m = 1.1 ...1.2).s.

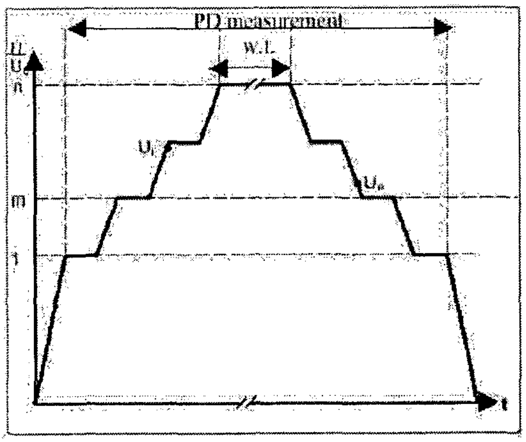

Fig. 2. Voltage-time characteristic of a combined PD and withstand test.

For EHV and HV cable systems the IEC Standards [1] accept AC test voltages in a frequency range 20 to 300 Hz. The highest realised test voltage was 400 kV, the highest (50 Hz equivalent) test power was 120 MVA, values up to 200 MVA are requested for the near future. With those parameters test systems on trailers are necessary. For the largest cable systems (e. g. London, more than 20 km 400 kV cable system) up to three ACRF systems (each on one trailer) have been used in a parallel operation mode. First tests for a 230 kV cable system, have also been performed. One ACRF system may test up to 12 km of a 230 kV cable system. A detailed report is given in reference [2].

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.

[Acknowledgement]

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[References]

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