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OFF-LINE MEASURING OF PARTIAL DISCHARGES ON HIGH-VOLTAGE ALTERNATORS

When changing from thermoplastic insulations used in rotating electric machines to thermoset insulations, the necessity has considerably increased to measure partial discharges with the aim of determining the origination of slot discharges in the stator of alternator [1].

Measurement of partial discharges with rotating electric machines can in principle be divided into the category of global measuring and that of localization measuring. In the global measuring of partial discharges, the partial discharges are measured across all the stator or in one of its phases all at once with the aim of, above all, watching the general state of insulation. The localization measuring consists in measuring partial discharges in a small section of the winding (as a rule, in one slot) with the aim of finding the point of occurence of partial discharges. Both the metods are complementing in practice. By means of the global measuring, which is not exacting as to preparation and the measuring proper, a machine of a high partial discharge intensity can be found, and by means of the localisation measuring the point of occurence of dangerous partial discharges can, finally, be determined on that machine.

Global measuring of partial discharges can carried out by different methods, but the widely known method is that with sensing RLC element. An advantage of this method is a high sensivity and a good resolution of individual kinds of partial discharges and the fact that its use is not limited either by the magnitude of capacity of the test object or by the magnitude of the test voltage.

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In the high-voltage technics workplace of ČVUT - FEL there is used for global measuring of partial discharges with electric rotating machines the modified Dakin's method [2,3,4], which enables to measure an earthed object by using partial discharge measuring instrument MUT 8, produced by TuR Dresden. This method was used several times and included in the ČEZ Direction dealing prophylactic measuring of alternators [5].

Measurement of maximum apparent charge q_{max} and sum charge Q in a supply voltage half-cycle is carried out with the alternator shut down (i.e. "off-line" measuring of partial discharges) in connection according to Fig.1. The phase measured of the stator winding is unearthed and fed from a continuously controled alternating-current source, while the other phases are earthed. Connected to the measured phase via coupling capacity C_v = 100 pF is measuring impedance H 18 (Z_m = 150 ohm) of partial discharge measuring instrument MUT 8 (produced by TuR Dresden). Partial discharge signals sensed by impedance H 18 and electronically adapted to be in a form suitable for further processing come to partial discharge measuring instrument MUT 8. The signals are first conveniently attenuated in MUT 8 input unit, and in the selection unit there is to be selected the measuring regime (polarity of pulses measured, polarity of voltage half--wave measured, time of gate opening, and the like), and/or connected a high-frequency filter. The selected pulses are then transferred to further processing in the selection block q_{max}, and thus also via the integrator attenuation to the integrator, which evaluates Q. The values of maximum apparent charge q_{max} and those of sum charge Q in a supply voltage half-cycle are then read on pointer indicators provided with a convenient damping. For illustration and a better differentiation of interferences from partial discharge pulses measured it is recommended (especially in gauging) to watch signal Q (and/or q_{max}) coming from measuring instrument MUT 8 on the oscilloscope screen as well (see Fig.1). For the purpose of determining the absolute values q_{max} and Q it is necessary for the wiring and all the transmission path to be gauged by a known charge value. The gauging is carried out with the circuit in no-voltage condition by calibration pulse generator PET 1 (produced by TuR Dresden), which originates, in course of every supply-voltage half-cycle, calibration charge pulse q_o. The calibration pulse generator is connected (introduced) between the high-voltage electrode and earthing (dashed in Fig.1).

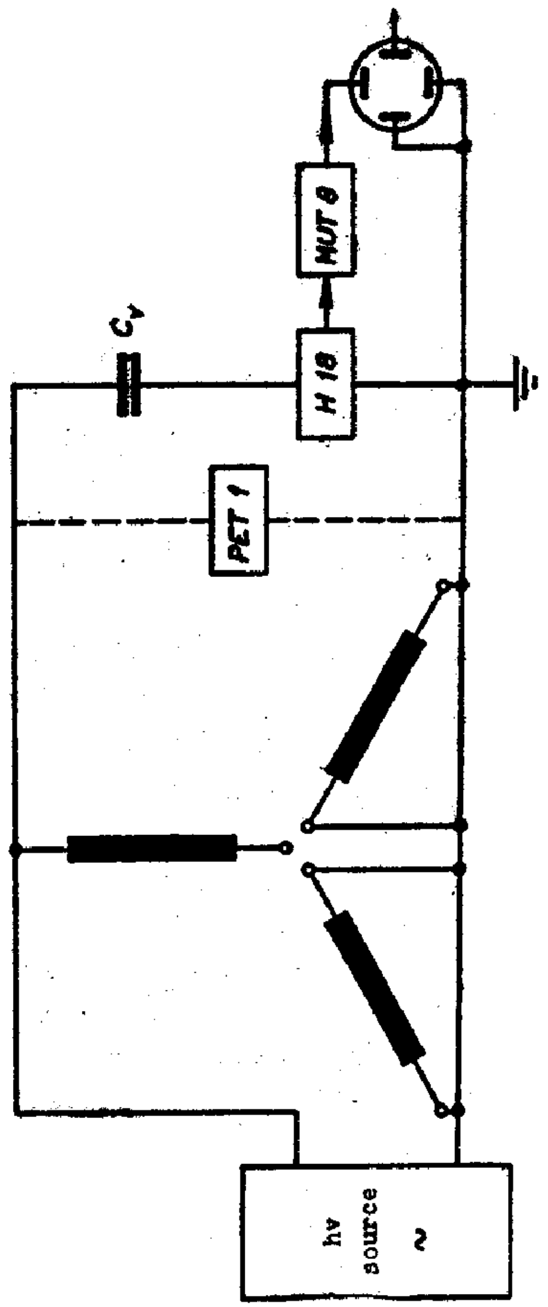

Fig.1.

The magnitude of maximum apparent charge q_{max} and sum charge Q of partial discharges in a supply-voltage halfcycle is then:

$$q_{max} = \frac{q_o\, A_q}{A_{q_o}} \cdot 10^{\left(\frac{T_1 - T_3}{20}\right)} \quad [C] \qquad (1)$$

$$Q = \frac{q_o\, A_Q}{A_{Q_o}} \cdot 10^{\left(\frac{T_1 + T_2 - T_3 - T_4}{20}\right)} \quad [C] \qquad (2)$$

where: q_o - calibration charge, [C]

A_q - indication of instrument MUT 8 (on q_{max} scale),

A_{q_o} - indication of instrument MUT 8 (on q_{max} scale), in calibration [divisions],

A_Q - indication of instrument MUT 8 (on Q scale) in measuring [divisions],

A_{Q_o} - indication of instrument MUT 8 (on Q scale) in calibration [divisions],

T_1 - damping of instrument MUT 8 input in measuring, [dB]

T_2 - damping Q of instrument MUT 8 in measuring, [dB]

T_3 - damping of instrument MUT 8 input in calibration, [dB]

T_4 - damping Q of instrument MUT 8 in calibration, [dB]

The partial discharge measuring with alternators is comparison measurement, which means that it is necessary to compare the values measured with identical or similar machines and that the same procedure of measurement must always be observed. The so-called "seasoning", i.e. leaving the object measured alive for a certain time before the measurement proper has also a great part. On the basis of practical experience the below-mentioned procedure for global measuring of partial discharges in the phase of the stator has been selected: Applied to the phase measured, unearthed and disconnected from the mains, is rated phase voltage U_{fn} for the time of 30 minutes. Thereafter the voltages is being diminished by 0,1 U_{fn} while registering q_{max} and Q within the interval of U_{fn} up to 0 (when only the external interference is measured). The values q_{max} and Q shall be found in both polarities and in both supply-voltage half-cycles; for evaluation the highest of them is considered. Calibration by a known charge q_o shall be carried out with the object in no-voltage condition, either before or after the measurement proper. The measured values will be processed to (1) and (2) and the resulting values of maximum apparent charge q_{max}, those of sum charge Q will be plotted in graphs in dependence on the applied voltage. When great increments or jumps occur in the curves q = f(U) or Q = f(U), or in case that there are great values of q_{max} or Q, it may stated that there is occurence of partial discharges in the insulation system. The dependencies measured of q_{max} = f(U) and Q = f(U) are compared with those measured in the preceding measurent. When there is a change in the course of q_{max} = f(U) or Q = f(U), it can be stated that the state of the insulation system is changed. The maximum admissible values of q_{max} and Q can be determined after a long-time regular measuring.

In Figs. 2 and 3 there are shown the typical courses of q_{max} = f(U) and Q = f(U) with the thermoplastic insulation "asphalt - mica" . The measurement was performed with an hydroelectric alternator of 10 MW, U_n = 10,5 kV (alternator G4, power plant "Kamyk"). It is obvious from the courses of the graphs of q_{max} = f(U) and Q = f(U) that the stator insulation displays a great number of small discharges (especially in phase U), that is to say at the rated voltage already. This corresponds to the practical experience with the thermoplastic insulation, which, especially after a longer time of operation, usually contains a great number of small cavities, and in which the classic slot discharges occur rarely. On measuring phase U, a high level of external interference was found (at U = 0 the $q_{max} \neq 0$ and $Q \neq 0$) due to the power plant operation (discharge lamp illumination).

In Fig 4 there is, moreover, shown dependence q_{max} = f(U) measured with an hydroalternator of 20 MW, U_n = 10,5 kV (alternator G4, power plant "Štěchovice") equipped with stator thermoset insulation "Relanex". Measurement of partial discharges was carried out before the routine repair of the alternator. The curve q_{max} = f(U) of phase W shows high values of apparent charge of partial discharges at the rated voltage U_{fn}. There was slot discharges in this phase.

Though in rotating machines the measured values of the maximum apparent charge are relatively high - q ≐ 10^3 up to 10^4 pC (in PVC cables the order of q is 10^0 pC, in oil transformers q ≐ 10^1 up to 10^2 pC) - yet the

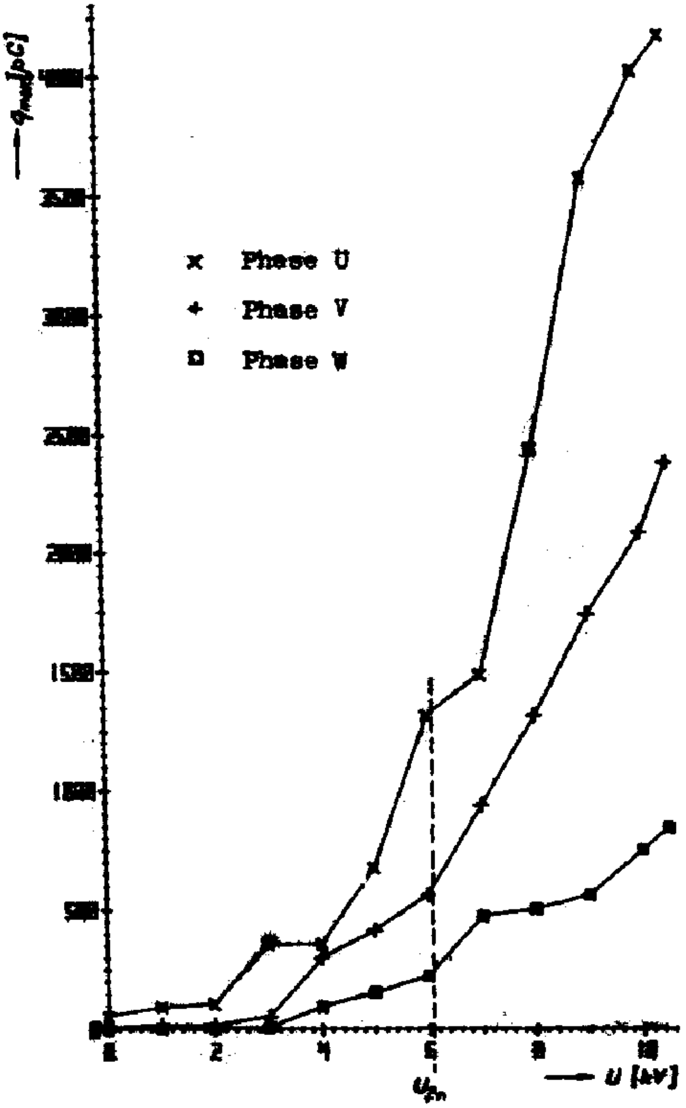

Fig.2.

greatest problem in measuring partial discharges in alternators in operation is a relatively high level and a broad spectrum of interference.This interference can be caused by various sources. Beside a corona across the bus-bars and partial discharges in the measuring circuit elements (supply transformer, coupling condenser, incorrect earthing, and the like), other interference sources can be represented by radio transmitters, radio-relay transmitters and radar transmitters as well as operating equipment of

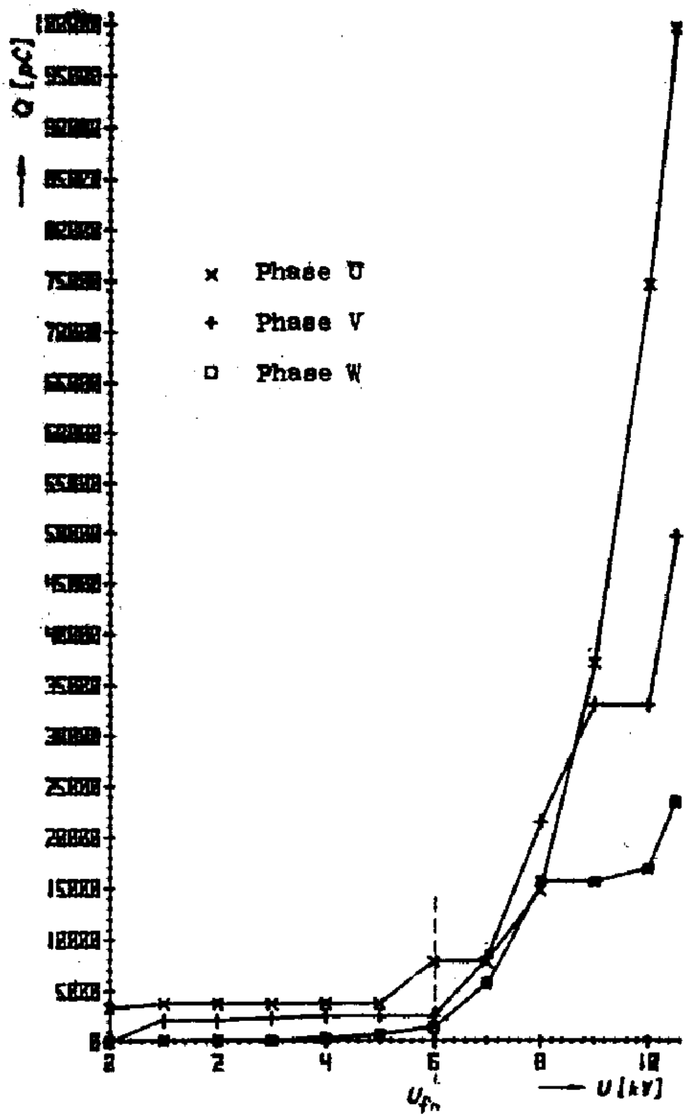

Fig. 3.

power plants (electrostatic filters, fluorescent lamps, discharge lamps, thyristor devices, and the like). That interference can be of a long-time, steady character. Very intensive, but short-time is interference caused by operational change-over of the power plant. For a high-quality measuring of partial discharges it is therefore necessary to eliminate

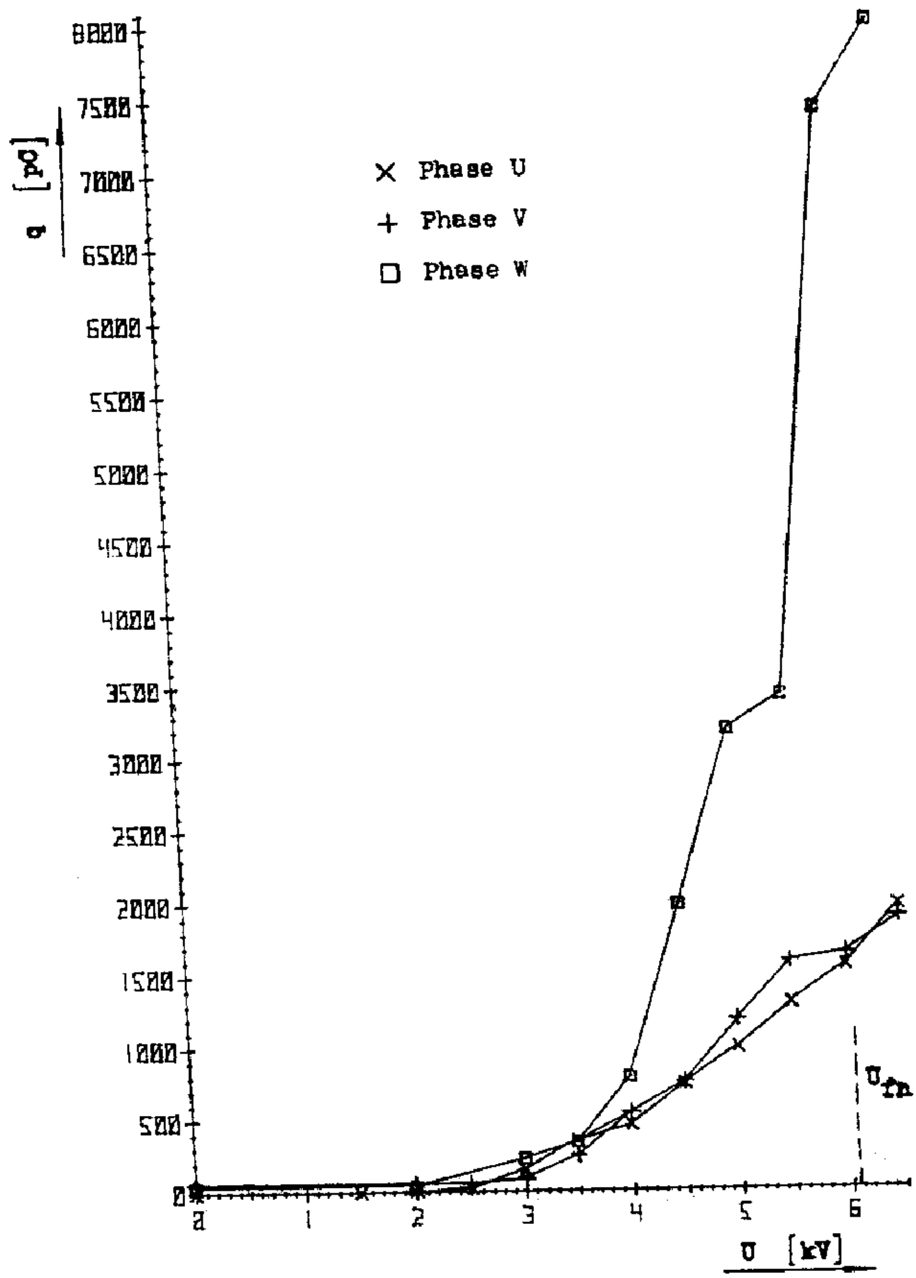

Fig. 4.

sources of interference and to reduce the interference level to such a low value to be negligible in regard to the level of the partial discharges measured. From the measurements performed by us until now we have gained the experience that for the purpose of reducing the interference level to an acceptable degree it is usually sufficient to ensure a coronaless wiring diagram of the measuring circuit, and/or utilization of filtres of lowpass type in order to suppress interferences in the mains.

The method of global measuring of partial discharges appears as a very perspective one, being especially convenient for orientation measuring of partial discharges in high-voltage alternators.

The advantages of the present method consist, above all, in its completeness, i.e., all kinds of partial discharges are measured in all the phase of the alternator stator all at once, its great sensivity, the possibility of measuring with no complex adaptation on the machine to be measured, and a relatively short measuring time and evaluation of results. That is why the present method is intended, above all, for prophylactic measurement of alternators during the time of their shut-down (revision). If the measurement of partial discharges with the same machine is repeated from time to time, it is possible to detect in time any worsening in the insulating properties of the insulation system and thus to prevent a possible breakdown of the machine.

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