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Question 1.01 contains several questions which will not be answered in total. The importance of combined and composite voltage tests is increasing, particularly für HVDC systems, but not very well handled in the existing IEC documents concerning high voltage tests and instruments and software used for measurement in high-voltage test. Therefore, a European research project “EMPIR project 19NRM07 HV-com²” was started dealing with the development of suitable calibration voltage dividers for combined and composite voltage and also for digital test generators for evaluating such test voltage and calibration of digital recording devices. The aim of the project is to prepare a proposal for the review of the Standard IEC 60060-1, “High-voltage test techniques – Part 1: General definitions and test requirements” concerning composite and combined wave shapes and it supports the standardisation of high voltage testing with composite and combined wave shapes and the related measurement devices.

The parameters concerning combined and composite voltage tests are clear for the type of voltages, according IEC 60060-1, but the tolerances should be more precise defined in future. The actual revision of IEC 60060-1 allows 1 % tolerance for DC and AC voltage at short time tests (< 60 s) and 3 % for longer test time. Ripple at DC voltage is allowed up to 3 % and for AC the ratio between peak voltage value and RMS value should be $\sqrt{2}$ within $\pm$ 5 %. For lightning and switching impulse voltage the tolerance for the test voltage is 3 %. The actual revision of IEC 60060-1 prosed a tolerance of the test voltage for combined and composite test voltage of 5 %, but added a note, that the tolerance values are under consideration.

In slide 2 the schematic test circuit for combined voltage tests is shown on the left side of the slide and it depicts clearly that the voltage across the test object can not be measured directly, but requires a calculation using the two voltage components. On the right hand of slide 2 the single voltage components and the calculated voltage across the test object is shown by an exemplarily combination of AC an impulse voltage. In such a case the resulting voltage stress amplitude is -2,5 U_0. It should be mentioned that the sign of the test voltage depends on the arbitrary direction of the arrow representing the test voltage U.

A further parameter influencing the test voltage is the time delay between the two applied voltages. In the revision is proposed: The tolerance of the time delay is ± 5 % of the front time of an impulse or ± 5 % of a quarter of a cycle of an alternating voltage, which is the longer time of the two voltages involved. This influences the test voltage in case of the combination of AC and impulse as well as in the case of two impulses. Slide 3 shows two examples for the time delay at composite voltage tests with AC and impulse as well as with two impulses. It is clear that the test voltage depends strongly on the time instant when the impulse voltage is applied in relation to the phase of the AC or the waveform of the impulse voltage. Also, in slide 3 a combined voltage evaluation is shown and, in this case, the peak value of the test voltage across the test object is not higher than the peak voltage of the AC component. On the righthand side of slide 3 the schematic circuit for composite is shown together with the required measuring recording devices. The measurement of the two voltage components U_1* and U_2* requires generally digital voltage recorders which are able to measure the relevant voltage component, however the digital recorder measuring the voltage across the test object should be able to record both voltage components with a sufficient uncertainty and time resolution. The calibration of such a voltage divider and the development of transient digital recorder (TDG) for the evaluation of the software of a digital recorder is also part of the European research project, which is not completely finished at the moment. Here are also the IEC standards IEC 60060-2 and 61083-2 and IEC 60060-3 concerned.

The last point concerning the optimisation of the test circuit for composite test voltages depends on the performance of the test generators and the requirements on the test voltage. The selection of the coupling and blocking element contains always a kind of compromise concerning the voltage which is coupled from one voltage source to the other one and the transfer of the voltage to the test object. In the schematic circuit on the righthand side of slide 3 it can be seen, that the elements between the voltage sources and the test object have to tasks, the blocking of the opposite kind of voltage and the coupling of the corresponding kind of voltage.

Slide 4 shows the summary for combined and composite test voltage circuits and measuring systems.

A general conclusion is: “Even in the so called old-fashioned high voltage test and measuring technique are some tasks open”.