

Experiences with Stationary and Mobile Calibration Laboratories

Reprint

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EXPERIENCES WITH STATIONARY AND MOBILE CALIBRATION LABORATORIES

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Abstract

Publication IEC 60060-2 [1] recommends the requirements on the measuring equipment of high voltage laboratories. The operators of the laboratory have to assure that the measuring uncertainties stay within the prescribed limits. The inspection are preferably done by an accredited laboratory through comparison with a reference measuring system which is traceable to national standards.

A high voltage calibration laboratory is illustrated, which can be operated either stationary in a high voltage laboratory or mobile on-site. The type of equipment and the necessary procedures for the performance checks and tests are described. The experiences after two years of operation are summarised. Moreover the operating costs and re-calibration intervals are commented.

1 Introduction

Publication IEC 60060-2 describes a procedure to establish and ascertain adequate precision for high voltage measuring systems as applied for regularly use in laboratories. Any measuring system (MS) can be qualified to become an approved measuring system (AMS), if the specific procedures are performed to monitor the systems throughout their service life. This can best be made by a reference method through comparison with a reference measuring system (RMS), which quality must be high and its overall measuring uncertainty must be known and always less than that of an AMS.

The most expensive equipment necessary to apply the reference method is, however, the generator for producing the high voltages. As the measuring systems to be calibrated are inherent to the generators, reference methods are most economical, when applied on-site in industry or research laboratories, thus to avoid transportation of generally large measuring systems to accredited calibration laboratories. However validation of testing and adopted procedures throughout the calibration has to be fulfilled by experienced, authorised operators.

This contribution does not emphasize the calibration technique for high voltage test apparatus, but is rather assigned to the practical situations on performing the procedures of IEC

60060-2 and IEC 61083 [4] which are widely accepted but unfortunately not yet thoroughly known to quite a great number of users.

2 Haefely Trench Calibration Laboratory

The described calibration laboratory is an independent unit at the Haefely Trench factory in Basle (HTB), Switzerland. It has been established in 1995 and accredited according to EN 45001 [2] under the approval of PTB (Physikalisch Technische Bundesanstalt) in Braunschweig, Germany in 1997. The laboratory is run under individual structure and responsibility which released the activities from other HTB routine commercial units. These assure the independent constitution of the laboratory. Accordingly the laboratory has its own quality management system providing appropriate documentation and internal audits. The certificates of calibrations are issued only by the management of the calibration laboratory.

To maintain the stability of the established uncertainties the calibration equipments are stored in a special, climate conditioned rooms and are only operated by specified, experienced staff of the calibration laboratory. For on-site use carefully designed transportcases are prepared for each equipment.

Since the highest test voltages are well defined in IEC 60071-1 [3] and comparison tests can be made at voltages as low as 20% of the rated measuring voltage of the system to be calibrated, only adequate RMS of moderate voltage ratings need to be acquired, see Table 1.

Highest test voltage		Voltage of the measuring system			
Type of voltage	Voltage kV	Test	20% acc. to IEC 60-2	Type	Nominal kV
Impulse Voltage		max. value of standardised peak voltage according to IEC 60071-1			
	LI	2400	480	RMS LI 500	500
	SI	1550	310	RMS SI 500	500
AC	1000	Routine tests of instrument transformers & bushings	200	RMS AC 180	180
				RMS AC 200	200
				RMS AC 600	600
DC	1075	Routine tests of HVDC components	215	RMS DC 180	180
				RMS DC 300	300

Table 1: Reference measuring systems of the HTB-calibration laboratory

Quantities, Ranges and Uncertainties of the laboratories are listed in the Table 2, which has been approved at HTB calibration laboratory. However, the correspondence of values measured in different laboratories on-site can be slightly deviated due to circumstances of the individual laboratory (e.g. grounding system, stability and harmonics of the applied or generated voltages, etc...). These have to be estimated and considered accordingly.

Quantity	Range	Uncertainty	Remarks	
Direct Voltage (DC)	0,1 V - 1000 V	0,02 %	measuring device	
	5 kV - 300 kV	0,4 %	measuring systems	
	300 kV - 900 kV	1,0 %		
Alternating Voltage (AC)	0,1 V - 1000 V	0,11 %	measuring device	
	1 kV - 200 kV	0,5 %	measuring systems	
	5 kV - 600 kV	0,5 %		
	200 kV - 1000 kV	1,0 %		
Impulse Voltage (LI, LIC, SI)	Peak value		measuring devices	
	LI	80 V - 1600 V		0,6 %
	LIC	400 V - 1250 V		1,0 %
	SI	80 V - 1600 V		0,5 %
	time param.			
	LI T ₁	0,84 μs		2,0 %
	T ₂	60 μs	2,0 %	
	LIC T _C	0,5 μs	2,0 %	
	SI T _P	20 μs	2,0 %	
	T ₂	4000 μs	2,0 %	
	Peak value		Measuring systems	
	LI	200 kV - 250 kV		0,5 %
	50 kV - 500 kV	0,9 %		
	50 kV - 2500 kV	1,0 %		
LIC	50 kV - 500 kV	1,0 %		
SI	200 kV - 250 kV	0,5 %		
	50 kV - 2500 kV	1,0 %		
time param.				
LI T ₁	0,8 μs - 1,6 μs	2,0 %		
T ₂	40 μs - 60 μs	2,0 %		
LIC T _C	0,5 μs - 2,0 μs	2,0 %		
SI T _P	200 μs - 300 μs	2,0 %		
T ₂	1000 μs - 4000 μs	2,0 %		

Table 2: Measuring uncertainties.

3 On-site Calibration

One significant advantage achieving by on-site calibration is the evaluation of the effective uncertainty of the measuring systems to be calibrated, which is inherent to its live influences on-site. Thus a mobile calibration laboratory have to meet additional requirements, which can be listed as followed:

- Low uncertainties of the equipments under different conditions including the robustness of the equipments against any hazard due to mechanical or thermal shock
- Appropriate volume resp. weight of the equipments due to transportation
- High flexibility in interfacing the equipments, e.g. earthing, connection typ / length, voltages, etc...
- Solid background of the calibration staff

During two years of operation many specified experiences on performing the calibration on-site are systematically recorded. Practical comments to these procedures can thus be outlined.

Preparation and Governing the Calibration Procedures

In the contract of calibration service a clear description of the extent and scope of calibration shall be defined in advance, so to avoid any misunderstandings. A check list which guidances to outline details of the calibration is therefore sent to the laboratory to be calibrated. Accordingly some preparations for the calibration on-site have to be fulfilled beforehand by the laboratory. Figure 1 shows the essential procedure from the enquiry up to the calibration certificate.

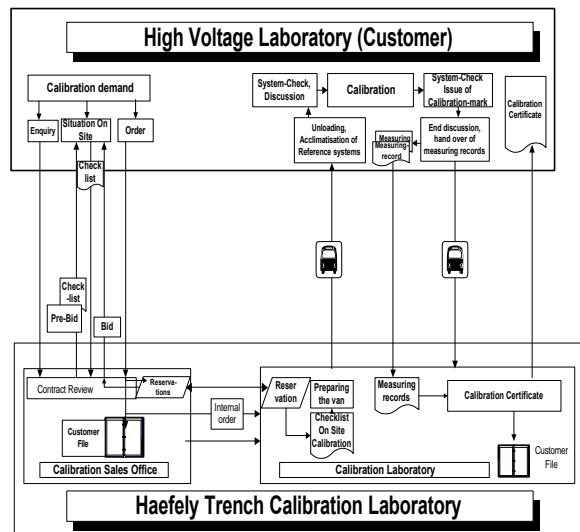


Figure 1: Procedure of an on site calibration

To improve the mobility and flexibility of the calibration service an exclusively purchased mobile is used to transport the equipments, see Figure 2. With well prepared checklists loading and unloading of the equipments are efficiently done. Accordingly used and returned of the equipments on every transportation are documented complying to the defined procedures of the quality management. Moreover the necessary checks before and after loading are prescribed.

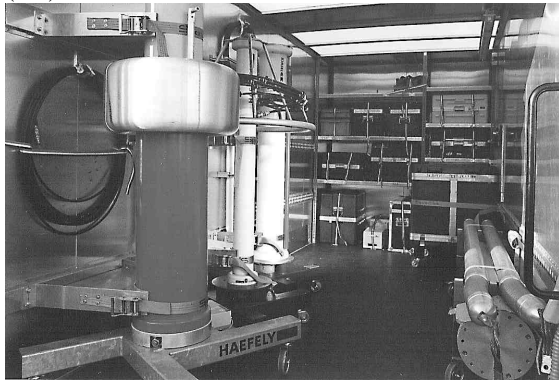
After arrival at the laboratory on-site the equipments are brought as soon as possible into the high voltage laboratory to acclimate the equipments to the environment temperature. Further necessary procedures may need sometimes to be discussed with the responsible engineer. Though the calibration procedures on-site are generally the same as at home, the equipments shall be regularly checked right before and after the calibration. For ambiguous circumstances the testing configuration and connections of the equipment shall be specially cared. Also it has to be assured that the high voltage generators are in proper condition.

After fulfilling the calibration the records and results of the calibration shall be handed over to the

responsible engineer and the calibration labels are directly sealed on to the calibrated equipments. The official issued of the calibration certificates shall be followed later on from the HTB calibration laboratory.



(2.1)



(2.2)

Figure 2: Mobile of the HTB-calibration laboratory for on-site calibration (2.1) inside view of the mobile and its whole equipment (2.2).

Significant Situations of the On-site Calibration

Though the acceptance of the replied calibration concept is widely effected, many details and procedures of the above mentioned standards are obviously not well known to many users. This induces in many cases difficulties to define appropriate content and extent of the calibrations. However, considerable amount of discussions and explanations with the test field engineer regarding test procedures and interpretation of the standards are commonly necessary.

In comparing to the former performed procedures (scale factor checks and component measurements) the method to maintain low measuring uncertainty by mean of periodic comparison requires more time, more equipments and operators. These consequently result in higher costs for the calibration. Many questions are thus arised to the necessity and the purpose of these extensive tests, especially when the strategy of the comparison test, which is based on the traceability of the whole chain of measuring systems from the national standards

down to the equipment under test, is not clearly understood.

A great number of old measuring facilities are still in use and part of them are in very poor condition. These systems are in fact near or over the limit of a possible calibration. Appropriate measures often have to be discussed with the users.

A great, unexpected calibration volume can also be resulted by a measuring system consisting of various low voltage arms for different scale factors. One has to made clear to the users that every different measuring cable and different part, which are in use for one measuring system needs a separate calibration. These reflect to the necessity of the clear details in the contract, which has to be thoroughly discussed with the responsible engineer beforehand.

Step response measurements, which assure specified dynamic behaviour of a measuring system for certain purpose and is preferably required for impulse measuring systems, were also made on-site in accordance to Annex C of IEC 60060-2 in the preferred circuit (step generator at a metallic wall). This configuration represents circumstances which is approximated to the conditions for high voltages measurements. However, it is often difficult to arrange appropriate space to achieve in many laboratories. Further discussions and practical compromises have to be made together with the responsible staff of the laboratory.

A well proved computer program should be used to acquire and evaluate the step response. However it has to be pointed out that the way of defining the virtual origin and the steady step level of the step response as suggested in the mentioned standard is obviously too sensitive to certain parameter changes to be used for evaluation. With a change in the choice of the steepest portion of the response or in the length-definition of the region to evaluate the steady step level different set of response parameters from the same step response figure can be achieved. It has been found out in practice that some particular programs applied intentionally such algorithms to target a set of response parameters of any improper behaved measuring system just only to conform the requirements according to IEC 60060-2. These evaluations or programs take advantage of the vague definitions of this standard and ignore completely the technical meaning of step response measurement. Unfortunately these details are not widely known to the users. The responsible engineer should be informed to be aware of, especially when a specification for purchasing a new measuring system is planned.

4 Results of Performed Calibrations

Despite the above mentioned problems with old facilities and different ratios the results of the calibrations were surprisingly good. All the calibrated AC-equipment were in the given limits according to the relevant standards. The scale factors of about 15% of the calibrated impulse measuring systems had to be corrected in order to fulfil the values of the tolerance band of IEC 60060-2. For the new fabricated measuring systems the correction was done by defining new scale factors, for an already in used measuring systems the factors for correcting the measuring results were documented in the calibration certificates.

Voltage shape	Range kV	Type of Calibrations				
		Total	Stationary	On Site	Re-Cal	F-Cal
AC	10-1000	41	14	27	34	7
DC	10-1000	36	36	0	6	30
Impulse	50-2400	35	18	17	22	13
Total		112	68	44	62	50

Table 3 : Record of the calibration.

The number and types of performed calibrations are listed in Table 3. This number is separated into stationary and on-site calibration respectively into re-calibration and so called factory calibrations (f-calibrations). Factory calibration means the calibration of new equipment which was manufactured at HTB and was calibrated before delivery. The amount of 44 contracts was addressed for on-site calibration, represents a 40% portion to the whole calibrated number. Subtracting the number of f-calibrations the percentage becomes 71%. This indicates that the advantage of on-site calibrations have been recognised and accepted widely.

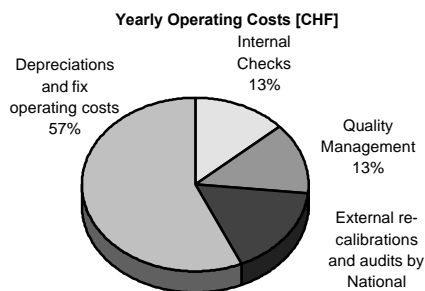


Figure 3: Expenses of the HTB-calibration lab.

5 Expenses for the Operation of the Calibration Laboratory

After two years of operation there is no general base for a reliable statement of the operating costs. Proportion on different cost categories are shown in Figure 3. It can be seen that beside the depreciation for the investment the expenses for the checks and

the re-calibrations are considerable. The increasing of internal demand (calibration on new fabricated measuring equipments) supports the effective cost of the laboratory and assures that the service price for on site calibration can be definitely limited to certain, attractive level.

6 Re-Calibrations and Performance Checks of the Reference Equipments

The traceability of the utilised reference measuring systems to national standards are carried out and approved externally at PTB. In accordance with this national institute of standards a period of every five years is decided. However, due to the being gathered experiences with mobile calibration laboratories it was agreed that the first re-calibration at PTB will be done after one year, to evaluate and to assure that the transportation, loading, unloading and the frequent changes of the environment conditions would effect negligible influence on the established uncertainty ranges.

For the internal checks different systems are compared to each other in a period of six months. Through this procedure deviations in the uncertainty of a measuring systems can be detected in the interval between the external calibrations.

Additional checks on the static and dynamic performance of the measuring systems are taken place before and after use / transportation of each system. The results of all checks and re-calibrations are stored in computer files and documented in the Record of Performance of the reference measuring system.

7 Conclusions

The accredited laboratory of Haefely Trench now has two years of experience with stationary and mobile calibrations. During this period more than 100 calibrations have been successfully performed. The on-site calibration services have been well accepted by international high voltage laboratories. Beside the evaluation of the effective uncertainty at users' laboratory low calibration costs and a shorter shutdown period of the equipments due to calibration are significant advantages for on-site calibrations.

8 References

- [1] IEC Publication 60060-2, High-Voltage Test Techniques, Part 2: Measuring Systems (1994).
- [2] EN 45001, General Criteria for the Operation of Testing Laboratories, 1990.
- [3] IEC Publication 60071, Insulation co-ordination, Part 1: Principles and Rules (1993)
- [4] IEC Publication 61083, Digital Recorders for Measurements in High-Voltage Impulse Tests, Part 1 (1991) and Part 2 (1996)

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