Chapter-10
High-Voltage Test Laboratory and Curriculum Experiments

Ravindra Arora
Professor (Retired)
Department of Electrical Engineering
Indian Institute of Technology Kanpur
Kanpur, Uttar Pradesh, India

Bharat Singh Rajpurohit
Associate Professor
School of Computing and Electrical Engineering
Indian Institute of Technology Mandi
Mandi, Himachal Pradesh, India

Objectives

- Application of high voltage laboratories
- Test equipment requirement in a HV laboratory
- Basic layout guidelines for HV laboratories
- High voltage laboratories in the world
- Experimental work for students as curriculum

Introduction

- For the development of technologies in scientific subjects, fundamental knowledge and concepts are evolved through continuous academic efforts supported by dedicated research work over decades, in some cases even over centuries.

- Laboratories are not only an essential requirement for any scientific development, but they are also an integral part of the institutions.

- Figure 1 shows a view of the medium size laboratory developed by the author atIIT Kanpur having; 200 kV ac power frequency test transformer, 500 kV impulse generator capable of producing both switching and lightning impulse wave shapes and a 400 kV dc test set.

- Unique feature of lab is that all these test voltages generated indoors can be brought out to an open air test bay with the help of a wall bushing installed in the laboratory.

- The laboratory is equipped with all major measuring instruments such as Schering Bridge with SF_6 gas standard capacitor having 100 kV rated voltage, PB detector, and 100 kV coupling-capacitor.

- Figure 2 shows the high voltage laboratory at CPRI having large test voltage generating equipment to cater to the testing requirements up to 1200 kV system.

(a)

(b)

Fig.1 HV laboratory developed at IIT Kanpur, India
(a) Indoor laboratory
(b) Outdoor test-bay

(a)

(b)

(c)

Fig.2 HV set-ups at CPRI Hyderabad, courtesy UHV Research Laboratory, Central Power Research Laboratory, Hyderabad.

(a) ±1200 kV, 200 mA DC Voltage Generator
(b) 1600 kV, 6 A, Power Frequency Voltage Generator
(c) 5 MV, 500 kJ, 25 stages, outdoor Impulse Generator

Requirement of Major High-Voltage Test Equipment

➢ AC Power Frequency Test Sets

- HV ac power frequency test sets may be required in a voltage range from a few kV to a few MV rating.
- To perform PB measurements on apparatus or on test samples, a major requirement is that the whole test circuitry is essentially PB free.
- Such a transformer at the HV laboratory at IIT Kanpur is shown in Fig. 4. This test transformer is rated at 100 kV, 100 kVA, and it is oil filled. The whole test set-up is PB free till up to 95 kV.

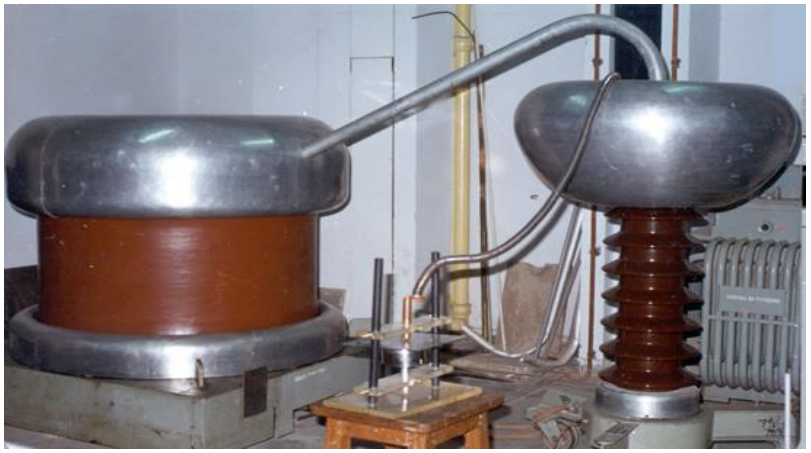

Fig. 3 A PB free 100 kV Transformer and 1.1 nF Coupling Capacitor setup in HV Laboratory at IIT Kanpur

Requirement of Major High-Voltage Test Equipment

➢ High-Voltage DC Test Sets

- HV dc is obtained with the help of rectification of ac power from a HV transformer.
- The basic HV doubler circuit by Greinacher and its developed versions are used to produce higher voltages up to 2000 kV, 100 mA.

➢ Impulse Voltage Generator

- Initially the impulse generators were designed to produce only the standard wave shape of lightning impulse voltage, ‘li’.
- With the increase in rated system voltages of transmission in the power system, necessity of testing HV electrical apparatus and insulators with ‘switching impulse voltage’ increased.
- The limitations in the size of the capacitor, multi-stage generator circuits are used in series for producing very high impulse voltages up to 7.2 MV, having 24 stages.

Layout of High-Voltage Laboratories

- The laboratories that cater to the needs of very high rated voltages, of the order of 800 kV and above, are therefore established outdoors as their requirement of space is extremely large.
- In a high voltage laboratory the equipment needed to be handled is so bulky that often the big indoor high voltage laboratories have a built-in crane system on the top, which can move the objects anywhere covering the total floor area.
- If the ceiling requirement of the laboratory is higher than a normal two-storey building, it would be desirable to provide a few balconies opening towards inside at a height which provides excellent 'observation platform' for observing the interesting tests live.
- The entry points, the doors, and the main gate, their shape, and size must be designed with due consideration to the movement of equipment and personnel.
- All good indoor high voltage laboratories have a provision to darken the hall completely.
- The control room in big laboratories is preferably a glazed chamber located at a place to provide a complete view of the laboratory.

➢ Clearance Requirement for Safety

- ➢ The high voltage laboratories require a specific guideline for the minimum fixed clearance between their electrical apparatus and the ground, walls, and other objects, that is, the safe distance in air between the live and the grounded objects for a safe operation.
- ➢ the clearance to all external structures should not be less than 1.5 times the length of the possible discharge flash overpath along the test object.

Layout of High-Voltage Laboratories

A100 kV transformer it works out as following:

$$\text{Minimum clearance} = \frac{1.2 \times 100\sqrt{2}}{5} \approx 34 \text{ cm}$$

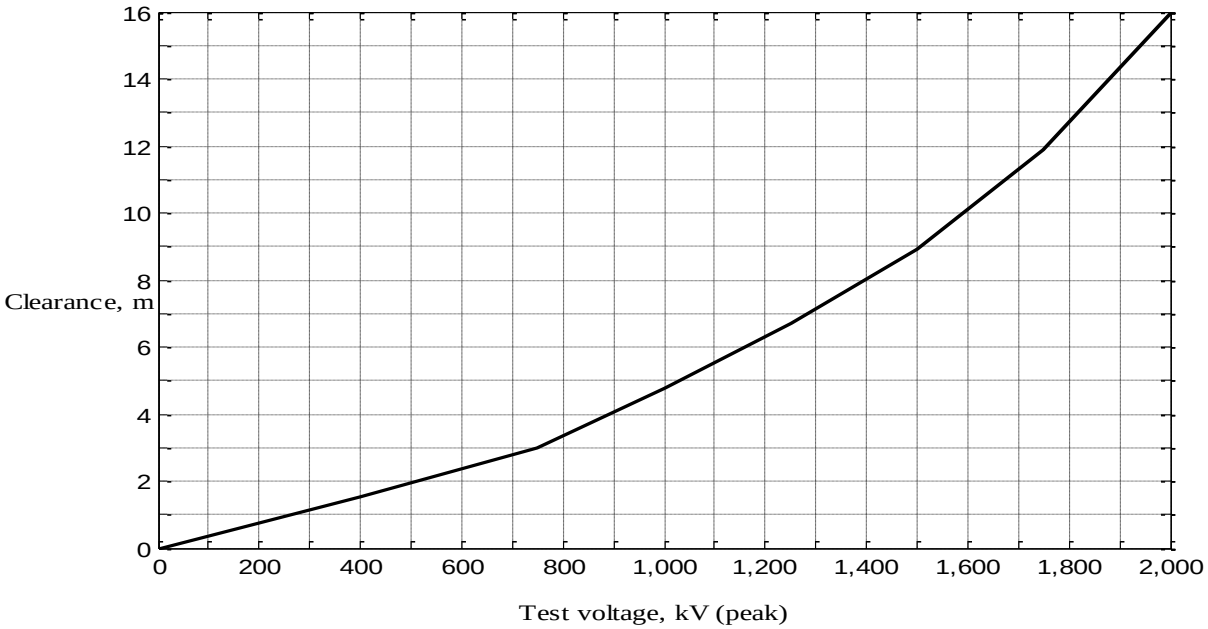

Fig. 4 Recommended minimum clearance of extraneous live or earthed objects to the energized electrode of a test object, during an ac or positive switching impulse test at the maximum voltage applied during test, IEC 60060-1 (2010)

Layout of High-Voltage Laboratories

➢ Grounding and Electromagnetic Shielding

- A ground or earthed system is established in the laboratory in order to obtain a stable ‘reference potential’, supposed to be at zero potential under normal conditions.
- An earthed metal grid, embedded in the laboratory floor, is installed with a ground point readily available at a suitable location.
- The grid under the floor is an iron rod mesh and it is connected to the identified common ground point by a large size copper conductor, as shown in Fig. 5.

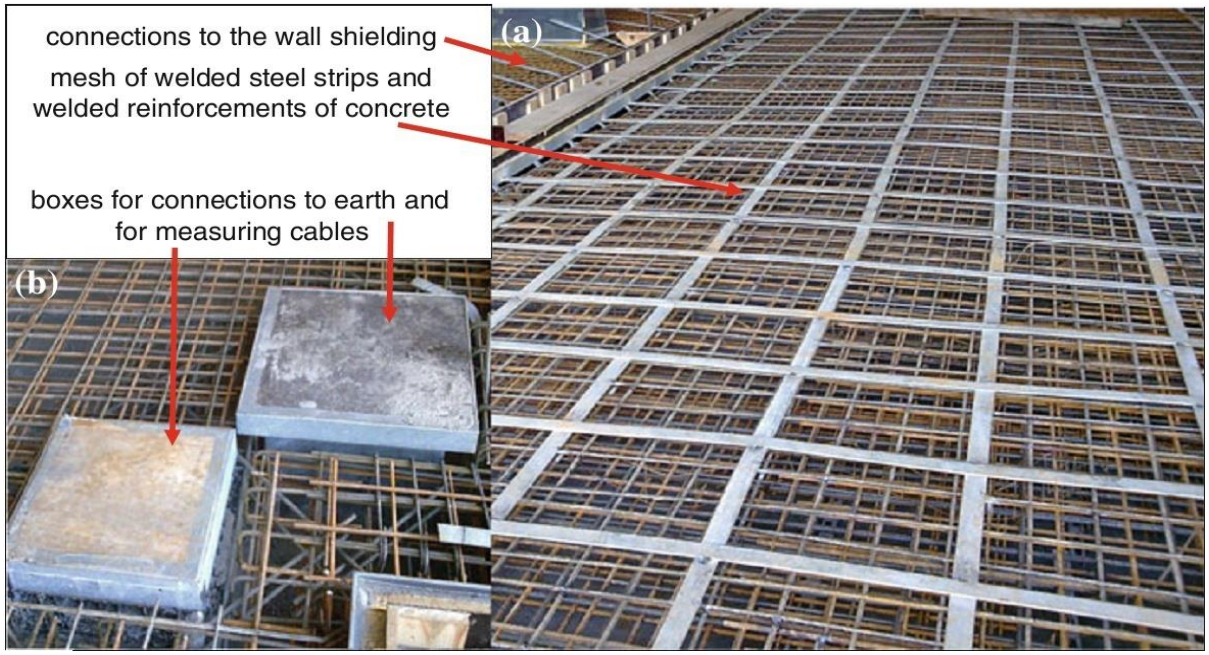

Fig. 5 Shielding of the floor of a HV laboratory. (a) Preparation of the shielding of the floor. (b) Earthing and connection boxes, [10.2]

High-Voltage Laboratories in India and Abroad

Table 1. (a) Major High Voltage Laboratories in India

Sl. No.	Location	Power frequency ac test facility		Impulse voltage test facility			High voltage dc (kV)	Laboratory layout		
		Voltage (kV)	Current (A)	Lightning		Switching		Length (m)	Breadth (m)	Height (m)
				Voltage (MV)	Energy (kJ)	Voltage (MV)				
1.	Central Power Research Institute (CPRI) UHV Lab., Hyderabad	1600	6	5.4	750	3.7		Open air laboratory		
2.	Bharat Heavy Electrical Ltd., Bhopal	1500	2	4.0	400	2.0		67	35	35
3.	Central Power Research Institute (CPRI), Bangalore	1800	2	2.4	30	1.5		50	40	35
								(Outdoor test facility also available)		
4.	Indian Institute of Science Bangalore	1050	1	3.0	50	1.6		37.5	30	20
5.	Government Engineering College , Jabalpur, M.P.	500	-	1.6	26.4	-		36	26	30
6.	Jadavpur University, Calcutta	250	-	1.4	16.0	-		25	15	20
7.	Indian Institute of Technology Kanpur	1. 100(PB free) 2. 200	1 -	0.5	4.4	0.45	400	14.2	8.6	4.35

High-Voltage Laboratories in India and Abroad

Table 1. (b) Major High Voltage Laboratories in the World

Sl. No.	Location	Power frequency ac test facility		Impulse voltage test facility			High voltagedc (kV)	Laboratory layout		
				Lightning		Switching				
		Voltage (kV)	Current (A)	Voltage (MV)	Energy (kJ)	Voltage (MV)		Length (m)	Breadth (m)	Height (m)
1.	Hermsdorf, Germany	2250 (3X750)	2	7.2	-	-	-	Open air laboratory		
2.	Russia	3000	-	7.2	-	-	-	115	80	60
3.	Les RenardiersElectricite De France, France	2250	1	7.2	450	6.0	-	65	65	45
4.	Hydro-cubec, Montreal, Canada	3300	2	6.4	400	6.0	-	82	67	57
5.	CESI, Milan, Italy	1200	-	3.5	200	2.5	1200	45	40	35
6.	Hitachi, Japan	1500	-	3.6	600	+2.0 & -3.0	±1200	60	57	48
								(also open air test bay)		
7.	University of Manchester, U.K.	800	-	2.0	-	-	±600	Floor area of 500 m^2		
8.	ASEA, Sweden	1500	-	3.2	140	-	-	47	25	25
9.	CEPEL Brazil	1800	2	4.0	200	-	±500	44	30	27

High Voltage Curriculum Experiments

- **Experiment–I** Classification of Electric Fields and the measurement of breakdown strength of atmospheric air in ‘uniform field’ .
- **Experiment –II** Distinction between the three Types of Coronas
- **Experiment–III** Generation of ‘Surface Breakdown’ in the form of Streamer and Leader Corona
- **Experiment –IV** Breakdown Characteristics of Atmospheric Air in Extremely Non-uniform Fields
- **Experiment-V** Study of HV Impulse Generator Construction and the Measurement of 50% Breakdown Voltage of a given Gap in Air
- **Experiment-VI** Measurement of Dielectric Power Loss Properties of Insulating Materials
- **Experiment-VII** Direct measurement of Insulation Resistance of Transformer Oil at room temperature by a Mega ohm meter
- **Experiment-VIII and IX** Measurement of Electrical Breakdown Strength of Liquid and Solid Dielectrics
- **Experiment-X** Pressure Dependent Behaviour of Atmospheric Air

Summary

- Development of high voltage laboratory requires careful implementation of acquired specialised knowledge and techniques.
- Higher is the level of voltage of the major test equipment, bigger the space requirement. The size of the equipment as well as the test objects is much larger and the clearance requirements are also longer at higher voltages.
- The subject of high voltage engineering is better understood while experimenting with the actual high voltage.
- Experiments, as part of the curriculum, communicate best to understand the subject.
- Detailed handouts, prepared for the laboratory experiments, are brought together and presented in this chapter.
- It provides guidelines for the respective institution and the instructor in-charge of the course to develop the apparatus and the set-up required in the HV laboratory to conduct the experiments.
- The experiments provided in this chapter, were developed and practiced as part of the course work at the high voltage laboratory at IIT Kanpur.

Thank You
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References

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